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STANDARD TYPES of PUMPING EQUIPMENT

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U.S. DEPARTMENT of AGRICULTURE FOREST SERVICE

INSTRUCTOR'S GUIDE
FOR
STANDARD TYPES
OF
PUMPING EQUIPMENT

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
CALIFORNIA REGION

APRIL 1970

FOREWORD

The material in this guide and the accompanying series of illustrations is intended as an aid to those people who are responsible for instructing others in the theory and operation of fire tankers and pumping equipment. This material presents a review of the basic theories and operating principles of the equipment in use today. It does not attempt to cover individual models of equipment, nor does it present techniques of operation involved in tactical fire fighting situations. It is presumed that the instructors who will use this guide have a working familiarity with these fire fighting tactics and the peculiarities of the actual equipment which may be used.

Those instructors familiar with the first issue of this guide, published in 1954, will note that the detailed information presented in the Appendices of that issue is no longer included. This information can be found in other publications such as ED&T Reports, Water Handling Equipment Guide, and Forest Service Manuals and Handbooks.

Instructors are strongly encouraged to supplement this material from their own experience. Additional teaching aids such as cutaway valves, gauges and pumps can be valuable. Color slides, photographs, and movies can be developed to meet individual teaching needs. The most valuable and most available teaching aids are of course the fire tankers themselves.

This guide will be amended or supplemented periodically as dictated by changes in equipment, or the need to provide expanded information on the subject matter, or information on additional subjects. Suggestions or recommendations for changes are welcome. They should be sent in memorandum form to Region 5 Division of Engineering, Equipment Management Branch.

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Section 1

AIR PRESSURE AND PUMPS

First, it would be well to discuss briefly what physical laws of nature make it possible for pumps to operate.

Let us start by reminding ourselves that we live in an atmosphere that not only surrounds us on all sides, but also is constantly exerting pressure against us from all sides and upon the surface of the earth be it land or water.

This pressure at sea level under standard conditions is 14.7 P.S.I.(pounds per square inch). The pressure is due to the fact that air has weight as do all other forms of matter, but let us bear in mind that air is gaseous and therefore, its weight by volume will vary proportionally to its density. This is why we measure air pressure under what is known as standard conditions, which are sea level Barometric pressure at a temperature of 59 degrees Fahrenheit. Under these conditions, the weight of air is 14.7 P.S.I. (pounds per square inch).

While discussing the weight of air, let us assume we are in the mountains at an elevation of 5,000 feet. Here we find the air pressure (or weight of air) to be about 12.2 P.S.I. At an elevation of 10,000 feet we find it to be about 9.7 P.S.I. This loss of weight is due to the fact that as we rise above sea level, we get higher into the atmosphere, which decreases the amount of air above us, and since air has weight, the less there is, the less pressure is exerted by its weight. Figure I illustrates the relationship between air pressure and weight of water.

Figure 1A shows a long vertical tube, with a cross-sectional area of one square inch, open at both ends with the bottom immersed in an open tank of water. As you can see, the pressure of the atmosphere is the same on the open end of the tube and on the surface of the water in the tank, therefore, the level of the water is the same in both.

If we close the top of the tube, as we have done in Figure 1B, the atmospheric pressure which is trapped in the tube is still the same as the pressure outside and the water level remains the same.

However, if we then add a vacuum pump (V) to the sealed end of the tube, as in Figure 1C, and pump out the trapped air, the situation changes. When we remove the air, the pressure created is removed also, leaving zero pressure in the tube. Therefore, the atmospheric pressure on the open surface of the tank will push water into the tube until the weight

of water in the tube creates the same amount of pressure as the weight of air outside, i.e. 14.7 P.S.I. As you can see, the water reaches a height of 33.81 feet. A column of water 33.81 feet long, with a cross-sectional area of one square inch, weighs 14.7 pounds.

Figure 1D shows a tube with a cross-sectional area of five square inches. Again, we create zero pressure in the tube by pumping out the air, and again the water is pushed up into the tube until it reaches a height of 33.81 feet. Obviously, there is more water in this tube than the one in Figure 1C. Since the atmosphere is pushing on five square inches with a pressure of 14.7 pounds per square inch, we need 14.7 pounds of water to oppose each unit of pressure. Multiplying 14.7 pounds per square inch times 5 square inches equals 73.5 pounds of water in the tube.

Just as a matter of interest, a mercury barometer works in exactly the same manner. The tube and the tank are filled with mercury instead of water. It takes a column of mercury one square inch in cross-sectional area and 29.92 inches high to weigh 14.7 pounds under standard conditions. As the atmospheric pressure varies slightly with the weather, the column goes up or down slightly. By marking the height of the column we measure the atmospheric pressure.

Section 2

PRINCIPLES OF PUMPING

In this section we will outline how our pumps depend on atmospheric pressure for their ability to pump. Nearly all pumps used in firefighting equipment are known as pressure type pumps. Pressure is the energy which enables the water to flow through the piping system of the pump unit and on through the hose line to distant or elevated places. It overcomes the retarding action of friction in the piping and hose lines, and it also provides the necessary velocity to discharge water from the nozzle.

Water can be supplied to a pump by common methods such as a tank or hydrant, or by what is known as suction lift (often called drafting). There is little to discuss where a pump is supplied by tank or hydrant so we shall omit that phase, and deal with the suction lift.

By creating a partial vacuum within the pump and suction hose, we find the effective pressure is considerably less than the normal atmospheric pressure acting upon the surface of the water supply in which the suction hose is immersed. The greater atmospheric pressure, acting on the surface of the water will cause the water to rise in the hose eventually filling the pump in the same manner that water filled the tubes in Figures 1C and 1D.

Other things being equal, we know that in a laboratory where tests may be made accurately the following conditionsdo exist:

1. At sea level at 59°F, air pressure equals 14.7 lbs. per sq. inch.
2. 14.7 P.S.I. will support a 1-square inch column of water 33.81 ft.high.
3. This column of water will weigh 14.7 lbs.
4. A 5-square inch column of water will weigh 5 times the 1-square inch column or 73.5 lbs.

There are limits of suction lifts. In actual pumping operations we cannot get a zero pressure (complete vacuum), but only a negative pressure (any pressure below 14.7 P.S.I. is negative pressure). This condition is present because of small air leaks in the pump, connections in piping, hoses, wear in the pump, and other mechanical defects.

In every day use with various type pumps, we find a suction lift of 26 feet at sea level to be very good performance.

We have found that for field use in fire tanker operation, the following "Rules of Thumb" can be used by fire tanker operators to a very great advantage.

1. One inch on your vacuum gauge equals, or will raise water by suction lift, one foot.
2. One P.S.I. of discharge from a pump will force water vertically two feet.
3. Each 1,000 feet above sea level will show a vacuum drop of approximately one inch.

These rules are conservative enough so that in most cases they will cover any loss by friction or other error.

Section 3

PISTON TYPE PUMPS

Piston type pumps are one of the oldest type pumps still found in use today. Many types are in use for high pressure spraying of herbicides and pesticides. Although the Forest Service does not use many for fire suppression, there are still a few in use. Most common examples are the John Bean, and the Wanner, which has the pistons arranged in a radial pattern, instead of side by side.

Piston pumps are known as positive displacement pumps because it is possible to measure a definite quantity of water or air for each complete cycle or stroke of piston travel; the amount displaced being equal to the volumetric (or cubic) displacement of the cylinder in relation to piston travel.

Turn to Figure 2 of our drawings; here a piston pump is shown in the various stages of operation.

Look at Figure 2A -- Note the location of the piston. It is at the bottom of the cylinder. Now look at Figure 2E. The piston is now almost at the top of the stroke. This distance between top and bottom of stroke can be measured, and the actual cubic volume computed in cubic inch displacement; thus the pump is said to be of the positive type.

Let us now go over the various parts which make up this pump:

A = Main body or cylinder barrel.
B = Piston assembly. Comprising the piston valve (V), piston cups (L) which prevent leakage between the piston and cylinder walls, and of course the piston-body itself.
C = Piston Rod. This is used to transmit a reciprocating motion to the piston, either by manual operation, or by some mechanical means from some source of power.
D = End Cap, discharge end. This serves to complete one end of the pump, and also serves as a guide for the piston rod and the discharge orifice "o".
E = End Cap, suction end. This cap completes the lower end of the pump. It contains the valve "F" known as the foot valve and provides a means of attaching a suction pipe or hose "G".

We shall now follow through the cycles of this pump by reference to Figure 2 - A,B,C,D, & E respectively.

Let us begin with Figure 2A. Here we have a dry pump with the piston at the bottom of the stroke, from the pump we have a suction pipe "G" to the water supply. Now look at Figure 2B. The piston is now traveling on the

up-stroke which by so doing is creating a negative pressure (or a partial vacuum) in the lower section of the cylinder. You will note that the foot valve "F" is open, and water is starting to pass through the valve and on into the lower part of the cylinder.

Looking at Figure 2C, we see the piston is now at the top of cylinder or top of the stroke; also, since the piston has stopped and is no longer pulling the water into the cylinder, the foot valve has closed.

Look now to Figure 2D. We find the piston traveling downward on the return stroke. The foot valve is still closed but the pressure on the water built up by the downward motion of the piston has forced the piston valve to open allowing the water below the piston to pass to the portion of the cylinder above the piston. When the piston reaches the bottom of the stroke and piston travel has stopped prior to starting of a new upward stroke, both foot valve and piston will be closed again as in 2A. At this point we have now finished one complete cycle of piston travel.

In the last Figure 2E, you note the upward stroke of the piston is in progress, and now water is being discharged through the discharge outlet. From this point on, it is only a matter of repeating more strokes of the piston to pump additional water.

Remember, a piston pump of this type is only as efficient as are the piston cups and valves in their ability not to leak. If these pumps remain dry over a long period of time, the cups on the piston will shrink, and the pump will fail. Try to keep them soaked with water, or oil, at all times. Any foreign matter such as sand or gravel, will cause a valve to remain partially open and leak, or will score the walls of the cylinder causing the piston cups to leak.

Section 4

DIAPHRAGM PUMPS

Diaphragm pumps are another type of positive displacement pump. They are commonly used for mud or trash pumps. They pump solid particles well because there are no sliding surfaces where particles can become caught and cause wear. The hand priming pumps on Forest Service model 60 (Class I), and some model 50 (Class II) tankers are diaphragm pumps.

Figure 3 shows the operating cycle of a diaphragm pump. As you can see, it is identical to that of the piston pump. However, the problem of wear on the cylinder and cup is eliminated by fastening the edges of the diaphragm and using a very short stroke on the piston rod to flex the middle of the diaphragm up and down. Since the short stroke cannot displace very much volume in comparison with the piston pump, this is compensated for by using diaphragms with larger cross-sectional area.

Remember, the diaphragm pump, like the piston pump, will only operate efficiently if there are no leaks. The bolts which clamp the diaphragm between the two sides of the pump housing must be kept tight. Any hole or rip in the diaphragm itself will make the pump inoperative.

Figure 3A is similar to the diaphragm pump shown in Figure 3 except that it is in a horizontal position and manually operated. However, maintenance of the pump also involves tightening of outside bolts, and internal nuts on the rod.

Section 5

ROTARY TYPE PUMPS

We find many types of pumps which fall under the classification of rotary pumps, such as vane, roller, gear and several others; however, we shall discuss only the types most commonly found at present in Forest Service work.

Gear Pumps

Like piston pumps, rotary pumps are of positive displacement type. Gear type rotary pumps consist of two intermeshing close-fitting gears mounted in a close-fitting case or housing. These gears are made in many designs, such as the common spur type gear which we find in the "Edwards" pump, cloverleaf design found in our "Pacific Marine" pumps, and the internal gear such as found in "Viking" pumps. However, the operating principle of all these pumps is the same.

Let us look at Figure 4. Here we have a typical gear type rotary pump such as the "Edwards".

You may have some doubt as to why we call this a positive displacement pump, and what makes the displacement in this type pump.

Bear in mind that each tooth on these gears has a definite cubic displacement with itself. By the same reasoning, each space between each two teeth has a definite cubic volume. You will also note that the gears are closely fitted to each other and to the pump case in which they turn.

Picture now in your mind that we are turning these gears (the bottom gear turning clockwise and the top gear counter-clockwise). As we turn these gears, you will notice the teeth on the right-hand side of pump are parting, leaving the area between the teeth vacant, thereby creating an area of negative pressure or partial vacuum. Since this is taking place opposite a point in the pump case where we have an opening, it is safe to assume that if this opening is exposed to the open air, or has a hose leading into a supply of water nearby, that atmospheric pressure is going to force air or water into the area of partial vacuum.

Now continue to turn the gears and you will find the areas between the teeth filled with water which will be carried between the teeth and the pump case until the water is on the opposite side of pump. We find that on the left-hand side of pump, the teeth are going into mesh, and that the space between the teeth, which now has water, is being occupied by a gear tooth forcing the water out. This water must have some place to go, and since there is an opening on the left side of the pump, it must be the path through which the displaced water will follow.

The gear type pumps require simple but careful attention to keep them in operation. The packing glands should be just tight enough to stop excessive leaking around the shafts. If they are too tight, it will result in cutting of the shaft and glazing or burning of the packing. The bearings should be lubricated sparingly, as too much grease or oil will cause excessive heat and damage to the seals.

The main thing to watch in the care and operation of gear type pumps is to make sure that only clean water is allowed to pass through the pump. As the drawing indicates, the space between the gear teeth and case is very small (.003" to .005") Fine silt or sand will cause undue wear on the pump case and on the gears, which will increase their clearance to such an extent that the pump will no longer prime itself; however, any gravel or other large particles will cause immediate damage. To prevent foreign matter from entering the pump, the intake end of the hose should always be protected by a suction screen in good condition. In addition, the intake end should always be suspended in clear water and never allowed to rest on silt, gravel, or other foreign matter.

ECO Pumps

The ECO pump which is used on Class IV or Model 10 tankers in Region 5 and most of the other Regions must be discussed separately because it is a separate and distinct type of positive displacement pump. In the pump industry this type of pump is known as a Rotary Piston type. It operates on the same principle as the gear pump, but with two impellers which oscillate in a manner similar to that in which a piston reciprocates.

Figure 5 shows the parts of the ECO pump. The pump shaft, "A" rides in friction type bearings "B", which are made of carbon. The shaft is usually connected directly to a motor by a flexible coupling on the left end. Two cams "C", ride on the shaft and turn with it. The cams oppose each other so that the vibration caused by one is balanced by the other. The cams turn inside the impellers "D". As you can see in the end view of the pump, the cavity in the pump case is slightly larger in diameter than the impeller. As the cam turns it pushes the impeller against the case at the spot in line with the cam. As the cam turns, the contact point between the impeller and case travels around the circumference of the impeller. Note that the impeller itself DOES NOT ROTATE. It merely oscillates as the cam rotates inside. The divider bar "E", which is held in place by the two set screws, serves to separate the intake and outlet sides of the pump, and also prevents the impellers from turning. This divider could just as well be made a part of the pump case. The main reason it is a separate piece is simply to make fabrication of the pump easier and cheaper. The packing gland "F" prevents leakage around the shaft. It is held by the gland adjusting nut "G", which in turn is held by the lock nut "H".

The ECO pump is available with several different impellers. They are all the same size and shape, but are made of different materials for pumping

different liquids. Different impellers should be used for pumping oil emulsions than are used for water.

Figure 6 shows the operation of the ECO pump. Look at 6A. Keep in mind that only the shaft with its cam turns. As it rotates, the cam pushes the rubber impeller out against the side of the pump case. Notice that only one point of the rubber impeller is touching the case. As this point moves clockwise past the inlet port it creates a negative pressure area so that the water enters under atmospheric pressure. In 6B, the shaft and cam rotates the impeller around to force almost all the air out. 6C shows the pump completely filled and water is being forced out the discharge port as it comes in the suction port. Since each revolution of the camshaft displaces a particular volume of water, this is a positive displacement pump.

There is relatively little maintenance on the ECO pump. The shaft bearings are lubricated by the pumped water. As in the gear pump, the packing gland should be kept tight enough to prevent excessive leakage but not so tight that the shaft is scored or the packing becomes glazed or burned. The important thing to remember with the ECO pump is that it should never be run dry. Since the bearings, and the impeller are lubricated by the water going through the pump, running dry for only a few seconds can cause serious damage.

An important point to remember about all types of positive displacement pumps is that since they do displace a particular amount of water with each stroke or revolution, you cannot completely close off the discharge without overcoming your source of power: That is, stalling the engine. Worse yet, if the engine does not stall, it is likely that the weakest part will fail, resulting in a broken gear, shaft, or pump case. To overcome this problem, we use a pressure regulating valve (also known as a relief or by-pass valve) on the discharge side of the pump. This relieves the pressure by spilling off or returning the water to the tank if it is not needed at the nozzle. The use and operation of the pressure regulating valve is further discussed in the section on Valves.

Section 6

CENTRIFUGAL PUMPS

Centrifugal pumps are unlike piston or rotary pumps in that they are not positive displacement, and have no definite volume discharged by each revolution of the pump.

They operate on the law of Physics that a body rapidly revolving about its axis creates a force directed outward from its axis of rotation, and proportional to the speed with which it revolves. This is known as "Centrifugal Force".

As an illustration, take a bucket partly filled with water and whirl it over your head. You find that the water does not spill as long as you do it rapidly. Also, if you will punch a small hole in the bottom of the bucket and whirl it as before, you find the faster you whirl the bucket, the faster the water will be forced out of the small hole, and much faster than it would run out if the bucket were not in motion.

Figure 7 is a cross-sectional diagram of a single-stage Hale centrifugal pump, such as the ones in our Class I and Model 60 Tankers.

Looking at Figure 7, we see the main case or body of the pump, "A". In centrifugal pumps this is known as the "Volute" case. (The name comes from the shape of the case.) The impeller "I" is fastened directly to the pump shaft so that it turns at the same speed and in the same direction. Notice the mechanical pump seal. The rotating part of the seal, which is usually made of carbon, fits on the pump shaft and is held against the stationary part by the internal coil spring which pushes against the impeller. The stationary part, which is usually made of ceramic or stainless steel, is held in a cavity in the pump case by a rubber seat, or cushion. The finely polished surfaces of the two parts of the seal prevent leakage of water into the gear case. The spring prevents large particles of gravel or other foreign material from getting between the surfaces, but fine particles will sometimes enter and cause wear. Since the spring compensates for wear, no adjustment of the seal is necessary. The drain plug "P" provides a means of emptying the pump case to protect against freezing.

At the left side of the pump is the gear case. The large gear "J" is driven from the source of power and in turn drives the small gear "K", mounted on the pump shaft. The assembly is known as the speed increaser. In order to reach the pressures we need, the pump impeller must turn at speeds up to 10,000 revolutions per minute (RPM). Since most of our truck and auxiliary engines turn at 3000 to 3600 RPM, the increaser is necessary.

Figure 7a is a similar arrangement as Figure 7 but it shows a different model Hale centrifugal pump. The seal mentioned above is also used by other manufacturers of centrifugal pumps.

Figure 8 has an edge view "A" and a side view "B" of a typical centrifugal pump impeller. This view "A" is a half-cross section allowing you to see how the water enters and exits the impeller; the side view "B" shows the top half of the outer face of the impeller cut away allowing you to view the spiral fins "V".

The impeller revolves in the pump case as is shown in lower half of view "A". There is very little clearance between the impeller and the pump case.

The position on the impeller marked "S" is known as the "Suction Cone". It is at this point that water enters the impeller. Position "O" is the discharge orifice in the impeller. Is is at the long slots in the outer edge of the impeller formed by the spiral fins "V". At this point, the water leaves the impeller and is collected in the cavity shown as "X" in view "A" and "B". This cavity in the Volute case is around the outer circumference of the impeller. It increases in area as it approaches the discharge port.

The pump illustrated is the "closed-impeller" type. There are many reasons why this type impeller is preferred over other types. The chief reasons are:

(1) Less loss through slippage between the water and impeller;

(2) Less sand or grit to wear against the walls of the pump case. Water entering through the suction cone passes through this closed sided impeller, thus preventing sand or grit from cutting out the walls of the pump case, which would, in turn, leave a greater clearance between the impeller and case. Any wear on the inside of the impeller which might occur would have little effect on the performance of the pump.

You will recall at the beginning of this discussion on centrifugal pumps, we mentioned that they do not have a positive displacement, and therefore will not prime themselves. (Except self-priming units, which are discussed later.) This being the case, we must prime the pump before we can start and perform any pumping of water.

On our Class I fire tankers, we find a hand-powered diaphragm pump, (discussed in Section 4). With this, we pump water into the case of the centrifugal pump, expelling the air. When all the air is replaced by water, the pump is primed. On our Class II and III tankers with centrifugal pumps, we use an exhaust primer to accomplish the same thing. The exhaust primer is simply a type of ejector which uses the engine exhaust gas in the same manner as a water ejector uses water from the pump to pick up more water. The operation and construction of these devices is fully explained in later sections.

Now that the pump is primed, lets see how it operates.

Let us now start the pump and turn the impeller at the normal operating speed of the pump. In so doing, we are causing the water within the impeller to revolve along with the impeller. Since the water is heavy and is being revolved very fast, we set up the force known as centrifugal force. This

will in turn, force the water away from the center of the impeller at point "S" (the suction cone), and by so doing we have created a negative pressure, or partial vacuum, at the center of the impeller, which is opposite the suction inlet of the pump. So by the same method we pushed water into positive displacement pumps, we push water into centrifugal pumps - by atmospheric pressure.

You can see in Figure 8A the path the water will follow from the suction inlet in the pump case; first through the suction cone of the impeller; second, the center of the impeller; third, the discharge orifice "O" of the impeller, and into the cavity in the pump case. As this action continues, the water in the volute cavity is pushed out the discharge by the water following behind.

Pressure vs. Volume

We must remember that, unlike the positive displacement types of pumps, the volume of water discharged from a centrifugal pump will change as the pressure changes. In a positive displacement pump, we move a given volume of water with each revolution or stroke. In a centrifugal pump we impose a certain amount of centrifugal force to the water going through the pump. At any given speed, this amount of force remains fairly constant. Therefore, if we have a lot of gallons going through the pump, each gallon receives less of this total amount of force than when only a few gallons are going through. This is why, as we open up the discharge valve of a centrifugal pump and increase the volume (usually expressed as Gallons Per Minute) the pressure (PSI) will go down. On the other hand, at a constant pump speed, in order to get higher pressure, we cut down the amount of volume. This can be compared to a man throwing a ball: If you throw a baseball as hard as you can, it will travel, lets say 200 feet. If you throw a basketball, which is of course much heavier, just as hard, it might travel only 100 feet.

Static Pressure

If we continue to close off the discharge of a centrifugal pump to increase the pressure, we eventually reach the point where the discharge is completely closed. At this point we have no volume and high pressure. This is known as static pressure, or static head. Closing off the discharge completely will not damage the pump immediately as it would in a positive displacement pump without a pressure relief valve. However, we must keep in mind that energy is still being put into the water. The laws of physics are such that energy does not increase or decrease in amount, it merely changes its form. In the case of a centrifugal pump with the discharge closed, this centrifugal force changes to heat. If the pump continues to put energy into only the water in the pump case, this water will become heated until it turns to steam. As it does the steam can expand and burst the pump case. At the very least, the steam will not adequately lubricate the pump seal, and it will be damaged.

In all our Class I and Model 60 Tankers, and most of our other centrifugal pumpers, we prevent overheating by using a very small bypass line back to the tank. Even with the main discharge closed, a very small amount of water is being pumped through this line all the time, which of course, allows a

small amount of cold water to enter the pump to keep it cool. Even with this safety feature, it is always safer to throttle a pump down and open the nozzle frequently to pump a little water if the nozzle is to be closed for any length of time.

Multiple Pumping

A single stage pump is one which has one impeller mounted on the pump shaft and turning within the pump case. By connecting two or more single-stage centrifugal pumps in series, i.e. with discharge of one connected directly to the suction of the other, there results what is known as a multiple-stage centrifugal pump. The volume of water pumped by each stage will be the same as the volume of the first stage, since all the following stages can receive only what water has gone through the first stage; however, each stage will increase the pressure an equal amount providing all stages are identical in design. We will cover more on multiple stages as we progress in our discussion of these pumps.

If we go back to the example of the man throwing the ball, we can see that there are only two ways to make the ball go further: One is to throw harder; the other is to pick it up after the first throw and throw it again. In comparing this with a centrifugal pump, we can throw harder by increasing the centrifugal energy, or increasing the speed. However, since the engines and gears on our pumps are limited to a certain speed range we must turn to the second method. If we take water that has been put under pressure by a pump, and put it through another pump, we raise the pressure still further. For example: A pump as shown in Figure 8C will discharge 30 gallons per minute of water at 150 PSI pressure. If we connect the discharge hose of that pump to the suction inlet of a second pump identical to the first, that 30 GPM will enter the second pump at 150 PSI. The same 30 GPM will leave the second pump at 300 PSI. Each pump raises the pressure of that given volume of water by 150 PSI, regardless of what the inlet pressure was. Let's take another example: If we connect a pump like those above to a hydrant under 50 PSI pressure, the water will enter at 50 PSI and be increased by 150 PSI, thus it will leave the pump at 200 PSI.

As you can see, pumping in series, or stages as illustrated above is a good way to increase pressure above that possible with a single pump. This is, in fact exactly the way pump manufacturers reach higher pressures - with multistage pumps. Instead of connecting complete pumps in series with one another, several impellers and volute cases are put together with discharge and inlet passages built in, and a single shaft driving all the impellers. Each impeller and volute case is one stage of the pump. As shown in Figure 8D there are four in series, as in a four stage pump.

The Hale, Cedco, and Darley pumps used on our Class I - Model 56 and 60, Class II - Model 50, and Class III - Model 20 tankers are all single-stage centrifugals with speed increaser gears. The Gorman-Rupp pumps used on the Class III PTO - Model 40 Tankers are also this type of pump. The only multi-stage pumps in Forest Service use at the present time are the portable units such as the Homelite-Terry T-7A and the Pacific Mark 3. Both of these are four-stage pumps.

Self-Priming Centrifugal

If you will remember the discussion on static pressure, this condition exists when the discharge is closed and the impeller simply slips in the water. When the pump case is full of air instead of water, the slight amount of pressure on the discharge side of the pump caused by hose friction is enough to raise a static condition. That is why a centrifugal pump cannot prime without some outside help to push the air through.

The self-priming centrifugal helps itself in a different manner. It is provided with a reservoir of water which surrounds and fills the impeller at all times. When the pump starts to turn, it throws the reservoir water out of the impeller by centrifugal force, creating a partial vacuum in the suction cone. Into the cone is forced air from the suction hose, and more water from the pump's own reservoir. As this mixture of air and water is pumped to the discharge side of the pump, the water falls back into the reservoir, and the air, being lighter, bubbles to the top. By recirculating the reservoir water, the pump always has a supply of heavier-than-air liquid to maintain the centrifugal force. Because of this continuous small amount of recirculation, even after priming is completed, self-priming pumps are generally not capable of as high pressures as the straight type of centrifugals.

The Gorman-Rupp 02F1, Figure 8E, which is used on the Class III PTO - Model 40 tankers, is the only self-priming fire pump presently in use by the Forest Service. However, most of the pumps used by the engineering crews in construction work are of the self-priming centrifugal type. If the pump is running at an excessive speed (over 2000 RPM PTO speed) the seal will be damaged beyond repair.

The operation and care of all the centrifugal pumps is about the same, be they single or multiple stage. The main cause of problems is an air leak. Any small leak, such as a faulty suction hose gasket or loose connection, will let air enter in small bubbles which will collect into one large bubble and stop the operation of the pump. Failure to remove all the air during priming may cause the same problem. Thus it is very important to eliminate all air leaks.

Another thing to avoid is running the pump dry. If the surfaces of the pump seal are allowed to rub together for more than a few seconds without water they will get hot enough to gall, or distort, causing leakage.

One thing which can cause trouble with a self-priming centrifugal pump is running it too fast while priming. If it pumps too fast, it will give the reservoir water so much velocity that it shoots past the point where it is supposed to fall back into the reservoir, and right out the discharge. This will, of course, soon empty the reservoir, destroying the ability of the pump to prime itself. Whenever the reservoir of a self-priming pump is empty, it must be filled from a bucket, hose, etc., before the pump will prime a suction line. Pumper data cards or manufacturer's instructions should be consulted for the proper speeds at which to operate while priming and pumping.

Section 7

VALVES

Valves can be described in any number of ways. However, the most common ways are by construction and by function. Let us first consider the various types of valves by construction: There are many types -- globe, gate, plug, ball, poppet, flapper, butterfly, etc. Figure 9 shows the operating characteristics of several of those commonly used on our tankers.

Globe - This is a manually operated valve. As you can see, the water has to make several twists and turns to get through the globe valve. This causes friction losses to the pressure. For this reason, globe valves are not used on our newer tankers.

Gate - This also is a manual valve. As you can see, it too causes quite a restriction until it is completely open. Again, these valves are not being used on newer tankers.

Plug - This is also a manually operated valve. An advantage of this type of valve is that it need only be turned through one-quarter of a turn to go from fully open to fully closed. A disadvantage is that it usually has a large amount of surface of the plug in contact with the body. This surface must be kept lubricated or the valve will stick.

Examples of this valve are the No. 6, or primer valve on the Class II and III pumpers with centrifugal pumps. The large three-way valves on some of the earlier Model 56 Class I tankers are also plug valves.

Ball - The ball valve works on the same principle as the plug valve: However, it is usually less bulky, has less surface to require lubrication, and generally is a more modern valve design. When fully open, it presents no restriction to the passage of the water. It has spring-loaded seals, so that no adjustments are necessary to keep it from leaking. Generally, the seals are carbon, rubber, or teflon, and the ball is chrome-plated or highly polished stainless steel. Therefore, no lubrication is necessary. Almost all of the manually operated valves on our present tankers are ball valves.

Butterfly - This is another type of quarter-turn valve. It consists of a plate shaped to fit the pipe with a pivot shaft through the center. When fully open it presents only a slight restriction to the flow of water. An advantage of this type of valve is that it is "balanced". Because the shaft is in the center, the force of the water which tends to push the valve open is counteracted by the force of the water pushing on the other side of the plate, or butterfly, which tends to push the valve closed. For this reason butterfly valves are used in large pipes. The No. 8, or suction line valve on our Class I tankers is a butterfly valve.

Poppet - Poppet valves are valves that are held to a seat by a spring, and rise off the seat when the force of the spring is overcome by some other force. A good example of a poppet valve is the modern automobile engine valve. The valve spring holds it to the valve seat until the cam lobe on the cam shaft overcomes the spring force. When the cam lobe releases the pressure, the spring returns the valve to its seat. There are several shapes that are used in poppet valves: The auto valve and seat are conical in shape; some poppets are a flat disc against a flat seat; others are a ball against a sharp-edged ring. Valve materials include steel, brass, plastics, glass, and ceramic. The pressure relief valves used on all the Class IV pumpers are poppet type valves. Most of these have a conical valve and seat made of brass. The water pressure overcomes the force of the spring to open the valve. The adjusting nut actually changes the amount of force applied by the spring, thus changing the pressure at which the water will open the valve.

The foot valves used on the bottom of our suction hoses are also poppet type valves. These are generally a flat disc type against a flat seat. Normally they depend on the weight of water above the disc to hold it against the seat when pumping vacuum is released. However, they sometimes have a light spring in addition.

Flapper (Swing Check) - Flapper valves operate by flapping shut by their own weight. They operate in one direction. That is after their own weight shuts them against the seat, any water pushing on them simply closes them tighter. However, water pushing from the other direction only has to overcome the weight of the flapper to open it. Most flapper or swing check valves have a brass flapper against a brass seat. Some have a rubber flapper with a steel or cast iron weight on it, working against a steel or cast iron seat. All of the fire tankers in use in the region use several swing check valves of the brass variety. Most of the self-priming centrifugal pumps used in construction work have the weighted rubber type of flapper valve at the inlet to the pump case.

In discussing the various types of valves classified by construction, we have touched upon the various functions of valves. To summarize briefly they are:

On - Off - All the manually operated valves we have described are used simply to prevent or allow water to flow past them.

Throttling - Again, all of them can be used to throttle, or regulate the amount of flow past them by opening them only part way. The globe and gate valves, which usually have threaded stems, can be used for a finer degree of control than the plug, ball, or butterfly types, whose whole range is covered in ninety degrees, or one-quarter turn.

In the operation of our fire tankers, we are generally not interested in using the valves for throttling. We control the amount of water we use by the size of the nozzle and the speed of the pump engine. Usually we want as much water as possible when the nozzle is open. For that reason we use the quick-acting, smooth bore ball valves, which offer the least resistance to flow.

Check - The check valves prevent water from flowing one direction, while allowing flow in the opposite direction. The flapper and poppet valves are generally the types used to perform that function.

Relief - The relief valve is used to relieve pressure from a system, as used on all our tankers with positive displacement pumps. They are generally the poppet type valve which has an adjustable spring to regulate the pressure at which it will open.

(Old valves of the various types described can be used to advantage as teaching aids. The internal parts can be shown by simply taking them apart, or by making them into cutaways to show the operation. Most forest shops have some old ones on hand, or will save them for you if you request them.)

Section 8

THE PUMPING SYSTEM

Previous sections have talked about the various basic components that go to make up the pumping systems used in our fire tankers. One thing which is covered in a later section is instruments and controls, which allow us to tell what's happening and make changes in the pumping operation. But really the only basic thing we need to do to make a system out of the components is connect them together with piping so the water can get through the system. Figures 10 through 14C show the variations in the piping used to provide the capabilities we have in our fire tankers.

Figure 10 shows the simplest type of system: The water comes from the tank to the pump, and out the discharge pipe. This system will work, but there is no way to control it or change its operation.

By adding an overboard, or stream-to pump pipe, as shown in Figure 11, we provide the option of using water from any number of different sources. The No. 1 valve is necessary to make the system work with the added pipe. If we were drawing water from overboard with the tank empty, the vents in the tank would allow air to enter the system at atmospheric pressure, destroying the vacuum needed to push the water to the pump. Thus the tank is closed off from the system by the No. 1 valve. When the tank is being used in the system, of course the overboard piping must be closed to hold vacuum. This is done with another valve, or simply a cap, as we shall see in later figures.

As we proceed you will note that we are numbering the valves as we add them to the system. This numbering system is standard on all our Forest Service tankers. That is, regardless of the fact that the No. 1 valve is in a different place on one tanker than another, it is always the valve that is opened to draw water from the tank into the pump. All valves of the same number have the same function on any tanker.

By adding a pipe from the discharge side of the pump back to the tank, as shown in Figure 12, we add the capability of refilling the tank. Again, valves must be added to close off the parts of the system which are not being used for a particular operation. The No. 2 valve closes off the tank-fill pipe when we want to discharge all the water available. The No. 3 valve is necessary to prevent air from entering the system or water from leaving when the No. 2 valve is open to refill the tank.

Figure 13 shows the system we discussed with the addition of the live reel or hose basket line and the truck mounted or truck protection line.

Figure 14 shows the system as it appears when a centrifugal pump is used. We have added the pipe to the priming pump and the valves necessary to make it work. The No. 6 valve is opened to make the primer a part of the system. The check valve operates automatically to close off the discharge side of the system while the pump is being primed, but let water into the discharge side as soon as pressure is developed in the system. Note that we have also added the pipe to the hose reel or basket. The No. 4 valve is necessary to close this discharge part of the system off when we want all the available water to go through the No. 3 valve to the larger hoses.

Figure 14A shows the system we have discussed with the addition of the pressure relief, or bypass, pipe which must be added when we use a positive displacement pump in the system. As discussed in Section 7, this valve opens automatically at a preset pressure to return water to the tank. Its purpose is simply to protect the system from pressures higher than that for which it is designed. On the newer Model 20 and 30 tankers which are used extensively in several of the other regions, the No. 7 valve has a control handle on it so it can be used to change the operating pressure of the system.

Figure 14A shows an overboard suction or draft line. When drafting, valve No. 8 is opened.

Reserve water (about 40 gallons) can be drawn to fill an ejector line, or for some other use, by opening the No. 9 valve which is shown in Figure 14B. When a suction hose is attached to the truck and the No. 8 valve is opened, the No. 1 and No. 9 valves are closed and the No. 2 valve opened to fill the tank.

Most of our other tankers have exposed piping systems which can be traced out on the tanker itself, instead of using drawings. One of the best ways to get a good working knowledge of any of the tankers is to have tanker crew members draw a schematic of the piping system on their own tanker and others.

Our newer Model 20 and Model 40 tankers have several additional valves to provide control. The No. 10 valve can be shut off so that the pump and plumbing can be drained while keeping the tank full of water. The large volume of water in the tank will not freeze as easily as the water in the piping and pumps, where more of the volume of water is exposed to the surface of the pipes, which conduct the heat away. The valve is located inside the tank, completely surrounded by the water, so that it too is less likely to freeze. The No. 11 valve is a small valve which is opened to drain the pump and plumbing, rather than having to crawl under the truck and remove various plugs with a wrench. The capability of draining the plumbing while keeping the tank full is important where tankers must be kept in service through the winter to provide structural fire protection.

Valve No. 12 is opened to allow water under pressure to flush out the coolant line. There is a 1/8 inch orifice in this valve which permits recirculation of water to provide adequate cooling of the pump and seal. To drain the tank by gravity, Valve No. 13 is opened. This valve may possibly be a pipe plug in the tank or line.

Figure 14C shows a welded manifold construction as used on the Model 40 PTO tankers. The same type of valves are on this manifold as shown on the previous charts Figures 11 through 14B.

Once you understand the basic parts that make up the pumping systems of our tankers, it should be fairly easy for you to trace the system through any of the tankers we have in use today. Sometimes you will find that a pipe or hose makes a detour from the straightforward path in order to be able to put a valve where the operator can reach it; or perhaps other outlets and fittings are included for gauges and controls. You will even find that some of our tankers use the same lengths of pipe for more than one part of the system, by routing the water in different directions for different uses. On some tankers high pressure hose is used for a particular part which on another is made of pipe. On our Model 40 patrol tankers most of the piping system is contained in a welded manifold in order to save space and make repairs more quickly. However, the basic workings of the system are the same. Probably the most complicated system we have is on the Model 56 - Class I tanker. Again, it is basically the same as the drawings, but the pipes must be routed to the rear so the valves are accessible, and all the pumping system components are routed among and around the drive system and other truck components, so it is difficult to follow. Figure 15 shows a schematic layout of the Class I tanker. You can see that instead of one line from tank to pump it has two. One of these is located so it can't draw all the water from the tank.

The standard numbering list for Region 5 fire tankers is as follows:

No. 1	from Tank to pump
No. 2	from Pump to tank
No. 3	from Pump to Overboard Discharge
No. 4	from Pump to Hose reel or basket discharge
No. 5	from Pump to small auxiliary discharge
No. 6	from Pump to Primer
No. 7	Adjustable pressure relief valve
No. 8	from Overboard suction to Pump
No. 9	Reserve supply from Tank to Pump
No. 10	Tank to Piping shut-off valve
No. 11	Pump and piping drain valve
No. 12	Pump coolant clean-out
No. 13	Gravity tank drain

Section 9

INSTRUMENTS AND CONTROLS

In order to know what is happening in our pumping systems, and be able to change what is happening, we must have instruments to tell us, and controls to let us make changes. As you have seen from Sections 7 and 8, the most common and most important control device is the valve, but there are some others. However, before we change what is happening, we should know if it needs changing. Some of the instruments which give us information about the system are:

Pressure Gauges - These gauges, as the name implies, tell us the pressure in the system, which is really the basic thing that we need to know. By coupling the pressure reading with various constants, we can really gain all we want to know about the system. For example, for any given nozzle size, once we know the pressure at which the water is flowing through, all we need to do is consult a chart to find the volume of water we are using. From that, if we know the size of the tank, and how full it was when we started, we can easily calculate how long our water supply will last. An opposite example is friction loss: If we know the length of a hose lay we can consult a chart to tell us how much pressure we will lose due to friction loss. We then need to know the system pressure to be sure we have enough to overcome friction loss and still do the job.

Pressure gauges work in a number of ways, but the ones we use on our tankers almost all work on the Bourdon Tube principle. The Bourdon tube is a "C" shaped tube with a flattened cross-section, as shown in Figure 16. The pressure exerted by the water inside the tube tends to straighten the tube. The higher the pressure, the straighter it becomes. If we attach the end of the tube to a gauge pointer by a linkage, then the movement of the end of the tube can be used to move the pointer in proportion to the pressure applied.

Since the Bourdon tubes of the pressure gauges are filled with water, damage from freezing is a danger. It is very difficult to remove the water from the gauge when it is connected into a piping system. To overcome this problem, some of the newer tankers are equipped with a Gauge Isolator System. This system consists of a rubber diaphragm which separates the tanker plumbing from the gauge and its connecting tubing, and a small bleed valve on the end of the Bourdon tube. The Bourdon tube and connecting line are filled with oil. The diaphragm holds the oil in, but is flexible enough to transmit the pressure from the water to the oil. The small bleed valve is necessary to let the air out while filling the system with oil.

Vacuum Gauges - Vacuum gauges do the same thing as pressure gauges, and operate the same way. However, since they read negative, or less than atmospheric, pressure they are usually calibrated in inches of mercury (in.-Hg) rather than P.S.I. Most of our Class I tankers are equipped with compound gauges, which read both vacuum and pressure. The vacuum gauge, or vacuum part of the compound gauge is important during priming. It tells us how much vacuum is being drawn on the system, which lets us know how close we are to getting water to the pump; whether we have air leaks in the suction side of the system; etc.

Tachometers - Tachometers indicate engine speed and are usually calibrated in revolutions per minute (RPM). They are not necessary on the tankers which are driven by auxiliary engines because the speed of these engines is automatically controlled by a governor which is built into the engine. However, on our power-take-off tankers, where the pump is driven from the truck engine, they serve several necessary functions: The first is to indicate when we are overspeeding the engine, which can damage the pump, and in severe cases, the engine itself. As we learned in Section 6, most of our pumps are driven through speed increaser gears, which turn the pump impeller more than three times as fast as the engine. Overspeeding can damage the pump seals, and since they are turning at speeds over 10,000 RPM, impellers can fly apart from the tremendous centrifugal force exerted on them, especially if they have flaws in the metal.

Since the speed of the engine is proportional to the pressure developed by a centrifugal pump, the Tachometer can be a good indicator of various types of malfunctions. Once you become familiar with a particular tanker, you know what pressures can be expected at various engine speeds. Anytime you notice a sudden change in this relationship, something is wrong. It could be anything from air in the system to a broken clutch or gear, but a close watch on the tachometer will enable you to stop operation before more serious damage occurs.

There are two main types of tachometers - electrical and mechanical. Mechanical tachometers are driven by a flexible cable in the same manner as an automobile speedometer. However, the cable is connected to the truck power train ahead of the transmission, so that engine speed is recorded regardless of what gear the transmission is in. Because they are directly connected to the engine power train, mechanical tachometers are usually more accurate than the electrical type. They are also usually more expensive.

Electrical tachometers are driven by electrical impulses or current which vary in proportion to the engine speed. They obtain these impulses from the engine ignition system or by a small generator mounted on the engine which is turned mechanically by the engine and generates more current as it turns faster. The current or impulses are transmitted to the tachometer dial by wires. The accuracy of electrical

tachometers can be affected by atmospheric changes, interference, and other things which affect the strength of the electrical signal. They may vary as much as 100 RPM from the actual speed, but are usually within 25 - 50 RPM. Since they have fewer moving parts than mechanical tachometers, they are usually less expensive to purchase and to maintain.

Most of our Class I tankers are equipped with mechanical tachometers. However, the Model 40 and Model 60 tankers are equipped with electrical ones.

Hour Meters - Hour-meters indicate the time which a pumping system has been operating. While not directly related to the operation of the system, they have a very important indirect relationship: And that is, they let you know when various preventive maintenance operations are due. The whole objective of preventive maintenance is to be able to make repairs and adjustments when it is convenient for you, rather than when something breaks down. The hour-meter provides an automatic method of making it possible for you to know when these operations should be performed. There can be no more inconvenient time for adjustments or repairs than in the middle of an initial attack response to a fire!

Water Level Gauge - Our tankers have various types of gauges to indicate the amount of water left in the tank. The newer tankers are equipped with dial-type gauges which are operated by a float arm, similar to automobile fuel tank gauges. These are simple mechanical devices with little to go wrong. The Class II tankers use a simple plastic tube with a small red float that enables the water surface in the tube to be easily seen from a distance. There is also very little to go wrong with these, except that the inlet can get clogged with particles from dirty water, or the tube can become so dirty or discolored that it is no longer transparent.

Most of the Class I tankers use a mercury manometer type of level gauge which is calibrated in inches corresponding to the depth of the tank, rather than simply Full - Half - Empty. A reading of 36 inches indicates a full tank. A small piston pump is used with these gauges to purge the line leading from tank to gauge to make sure the reading is accurate. Since these gauges work on a pressure principle, actually measuring the pressure imposed by a column of water in the tank, any leaks through fittings in the lines or the packing on the purge pump, can cause inaccurate readings.

Now that we have discussed the instruments that tell you what's happening in the system, let's look at several of those which enable you to change what is happening - the controls. As we said earlier the valve is the most common, and probably the most important control device on our tankers. It is also the simplest. When you turn the handle, the inner part of the valve turns. Some of the other controls are a little more complicated in the way they operate after you activate them.

Pressure Controller - The Class I and Model 60 fire tankers are equipped with an automatic pressure controller which maintains the desired pressure in the pumping system regardless of changes in volume. To operate the controller you simply turn the dial on the controller until the desired pressure, as indicated on the pressure gauge, is reached. The controller will then vary the engine speed up or down as nozzles are opened or closed to keep the pressure constant. The pressure gauge itself is not part of the controller, however the control box contains a Bourdon tube which is connected to a small valve, rather than a dial pointer. This valve controls the amount of engine manifold vacuum which operates a diaphragm connected to the engine throttle. As the pump pressure falls below the desired pressure, the tube bends, operating the valve, which increases the vacuum. The increased vacuum acts on the diaphragm which speeds up the engine, thus building the pressure back up to the desired point.

Since the truck engine provides only a small amount of manifold vacuum when it is working hard, friction in the controller mechanism or dirt or moisture in the connecting lines can have a drastic effect on its operation. The newer Model 60 tankers use air pressure supplied by the truck air brake compressor instead of engine manifold vacuum. The air pressure is about 50 times higher than the manifold vacuum, thus it is not so much affected by these factors.

Throttle Control - On all our tankers except the Class I and Model 60 units, the engine speed is controlled by a hand operated throttle which is connected directly to the engine carburetor by a flexible cable. On the Model 40 patrol tankers it is located in the cab, usually just inside the driver's door. On the older auxiliary engine driven tankers, the throttle handle is located right on the engine. On the newer Class II Model 50 and Model 20 tankers it is located on the control panel.

Emergency Shut-Off - Most of our power take-off driven tankers are equipped with an automatic control device which shuts the engine off or slows it down if it should start to run wild. On our Model 20 and Model 40 tankers this device is simply a pressure activated switch which shuts off the ignition if the water pressure in the system falls below the pressure at which the switch is made to open - usually around 40 or 50 P.S.I. Since the pressure in the system is less than that when we are priming and getting started on a pumping operation, we have a bypass, or over-ride, switch on the control panel which cuts the shut-off switch out of the system. After we get the pumping system up to operating pressure we include the automatic shut-off in the system by turning off the over-ride switch. The shut-off system cannot be used at all when we are going to be pumping at low pressures.

Our Class I and Model 60 tankers use a different type of emergency shut-off system. The power which is needed to turn these pumps at high output is close to the maximum horsepower of the engine itself. If the ignition were shut-off while the engine was working hard, the heat in the engine compartment would make the engine difficult to re-start quickly, such as may be necessary to move the tanker out of danger, or some other emergency. Therefore the shut-off system used on these tankers does not shut the engine off, it simply closes the throttle, bringing the engine speed down to a fast idle.

The system consists of a centrifugal vacuum switch and a small vacuum diaphragm which acts on the tanker pressure controller. The centrifugal vacuum switch is driven by a cable off the same gear that drives the tachometer. When the switch begins to turn faster than the speed for which it is set, it closes. This activates the small diaphragm mounted on the pressure controller, which over-rides the Bourdon tube and operates the manifold vacuum valve to slow the engine down.

Some of the newer Model 60 tankers use an electrical system instead of vacuum to operate the emergency shut-down system. The centrifugal switch is electrical rather than vacuum, and operates a solenoid valve in the manifold vacuum line to slow the engine down. This system operates faster than the older Class I system, and minimizes the engine surge which takes place before idling down in the older Class I Tankers.

An important maintenance item to note on Class I tankers is the operation of the tachometer. It is no problem to operate the tanker if the tachometer is operating improperly, or not operating at all. However, if the tachometer is not operating correctly, it is likely that the emergency shut-off system is also not working properly; since they are operated by the same drive gears. Any improper operation of the tachometer should be repaired by a mechanic as soon as possible.

Section 10

WATER EJECTORS

The water ejector is actually a type of pump with no moving parts. It is used as a part of many rural water systems, where it is called a "jet pump". As we have discussed in earlier sections, the laws of physics dictate that energy is never gained or lost, it merely changes form. In conventional pumps we convert mechanical work supplied by an engine into pressure and flow in the water being pumped. The ejector does not convert energy, it merely changes the ratio of flow and pressure. That is, it uses some of the pressure to increase flow. Because it starts with water pressure and flow, and ends with the same thing in different proportions, moving parts are not necessary. On the other hand, since a conventional pump is needed to supply the initial water flow and pressure, the water ejector cannot work independently, it is used only as a supplementary pump.

The cutaway view of a typical water ejector shown in Figure 17 shows how the ejector operates: Water from the conventional pump enters the water inlet and is forced through the nozzle at high velocity and into the constricted passage called the venturi. As the water squeezes through the narrowest part of the venturi it actually increases its velocity. This increased velocity creates a pull, or vacuum behind it in the entrance to the venturi. This vacuum causes water to be pushed into the suction inlet by atmospheric pressure. Therefore, we are using pressure to gain velocity, then using that velocity to increase the flow. We have a greater quantity of water flow at the discharge of the ejector, because that which entered through the suction inlet has been added to it, but we have less pressure.

The water ejector is carried on most of our larger fire tankers as a supplementary pump. By placing the suction inlet of the ejector in a stream or lake which can't be reached by your tanker suction hose, and routing the ejector discharge hose back into the tank, you use the pressure capability of the tanker to refill itself. This is the main reason for the 40-gallon reserve in the Class I tanker which is available through the No. 9 valve. The 40-gallons is enough, in most cases, to initially fill the hoses from the tanker to the ejector and back to the tanker. The same system can be used for pumping out pits or basins. Or it can be used on smaller tankers simply to increase the flow of the unit where high pressure at the nozzle is not necessary.

The amount of water which can be picked up by a particular size ejector, of course varies with the pressure at, or velocity through its nozzle. If the pressure is inadequate, then no water will be picked up. Therefore, it is extremely important that the ejector be matched to the pressure available. The most obvious thing affecting pressure is the

capability of the conventional pump. Another thing is the lift from the ejector to the point where the water is discharged. The pump must supply pressure for the lift in addition to the pressure needed to operate the ejector. Another factor is friction loss in the hoses.

Detailed information on the performance characteristics of specific water ejectors is available from manufacturer's literature, Equipment Development and Test Reports, and the Servicewide Water Handling Equipment Guide.

Figures 17A through D show various water ejector uses. Refer to Water Handling Equipment Guide for ejector performances versus pump ratings.

Section 11

EXHAUST PRIMER - ARRESTERS

All of the tankers in Region 5 which are equipped with centrifugal pumps driven by auxiliary engines, are equipped with exhaust primers. As shown in Figure 18, the exhaust primer is essentially an ejector which operates in the same manner as the water ejector discussed in Section 10. The only real difference is that instead of using water to provide the necessary velocity through the nozzle and venturi, it uses the exhaust gases from the pumper engine. Under normal operation the exhaust gas enters the spark arrester and flows out the top exit port. When the exit port valve is closed, the exhaust gas is forced to go through the nozzle and out the venturi. The low pressure at the venturi causes the air in the pump to be pushed out and water to be pushed into the pump and on through and out the ejector discharge.

Originally, the chamber which the exhaust gas enters as it comes from the engine was simply a muffling chamber. In order to avoid the necessity for mounting a conventional spark arrester on top of this chamber, or mounting the ejector on a conventional spark arrester, either of which would require cumbersome plumbing and special exit port valve mountings, the chamber was redesigned to be an efficient spark arrester. This was done by carefully designing the shape and angle of the entrance pipe so that it lets the exhaust gas enter at the correct velocity and at the proper angle to start it spinning. As the gas spins around the chamber and rises to the top, the carbon particles are spun to the walls of the chamber by centrifugal force and fall to the bottom. They are emptied periodically through the cleanout plug. Needless to say, the arrester does not function properly while the exhaust gas is directed through the ejector. However, during this time the carbon particles fall onto the truck bed and are soaked with water.

The exhaust primer-arresters used on the Hale-Cedco HPZF and HPZZ pumps on Class II, Class III and Model 20 tankers have been tested and qualified under Forest Service Standard 5100-1.

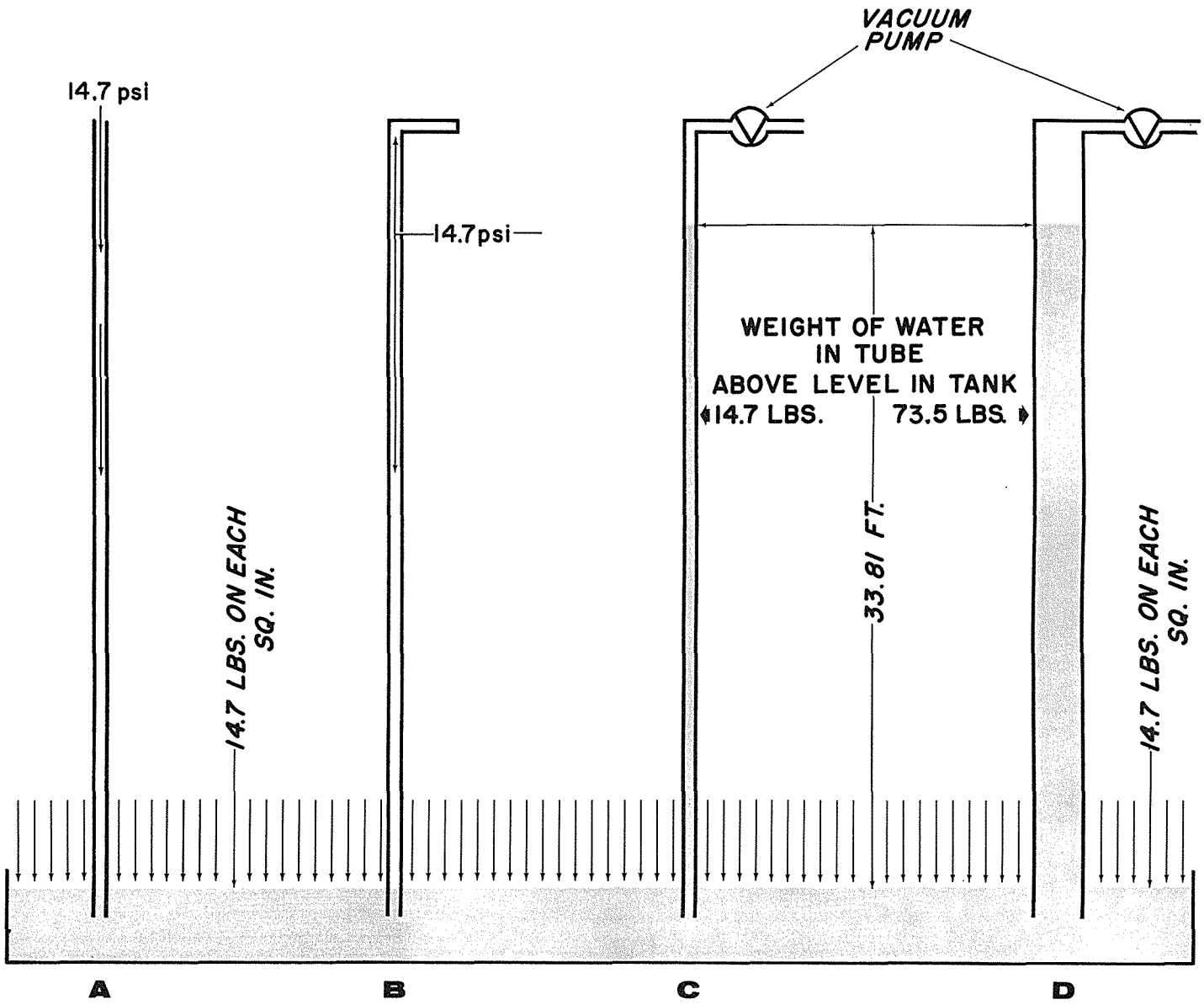
Section 12

POWER TAKE-OFF PUMP DRIVES

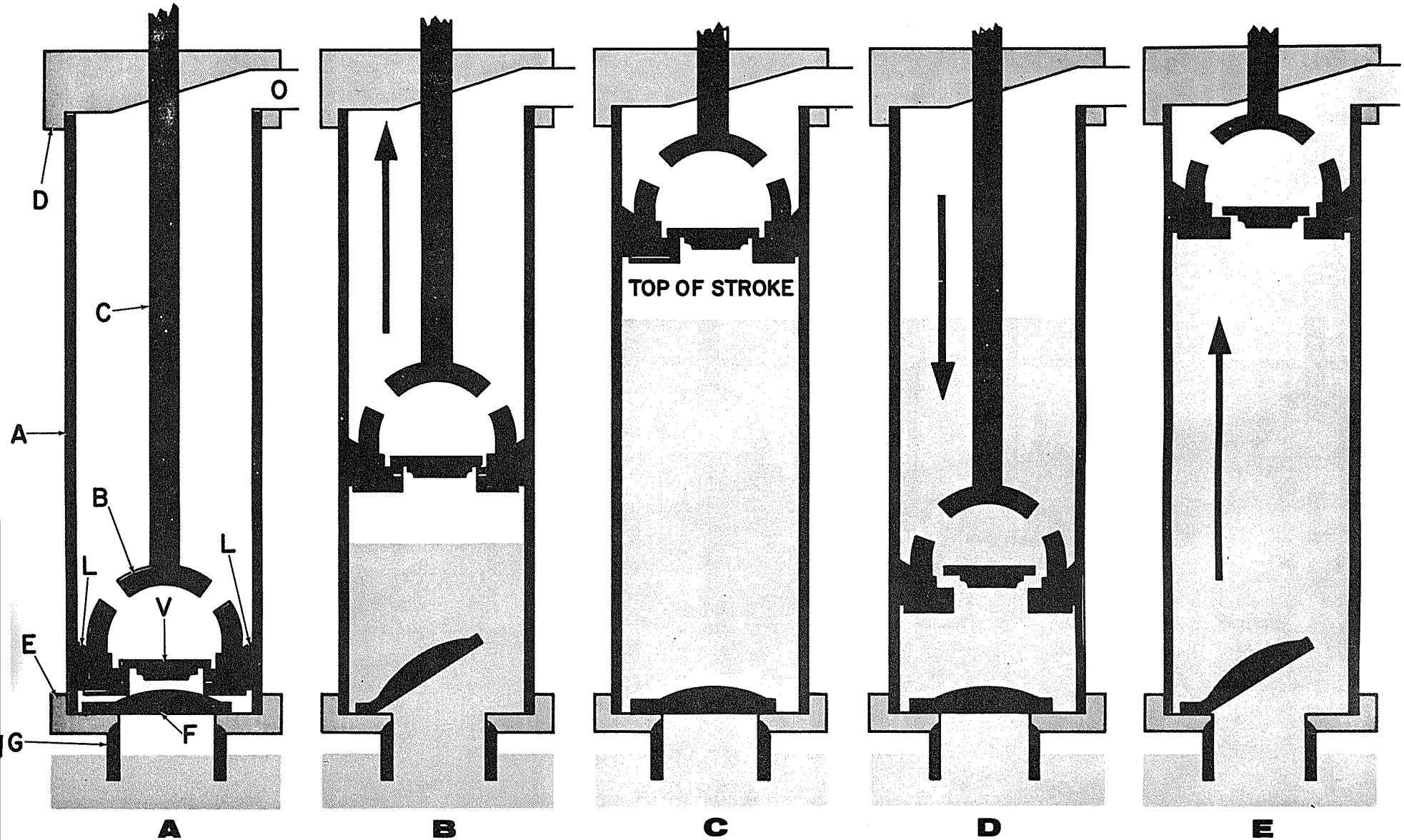
Figure 19 shows an older model Class I tanker PTO pumping system.

Figure 20 illustrates a Class III tanker PTO drive arrangement.

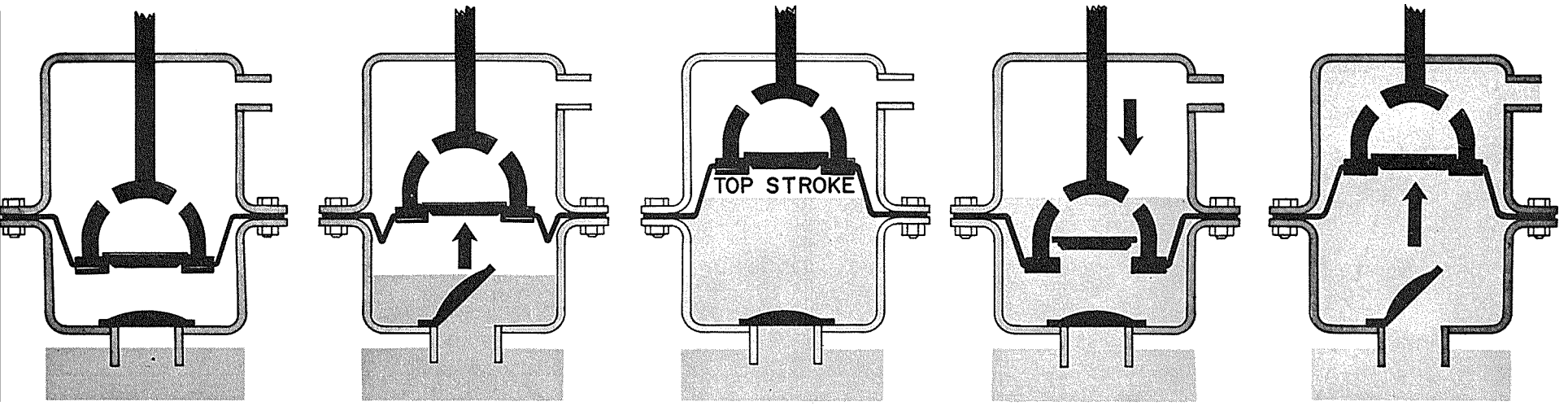
Figure 21 is a diagram of the Model 60 tanker flywheel PTO pump drive system.



AIR PRESSURE
FIGURE 1



PISTON PUMPS
FIGURE 2



DIAPHRAGM PUMPS
FIGURE 3

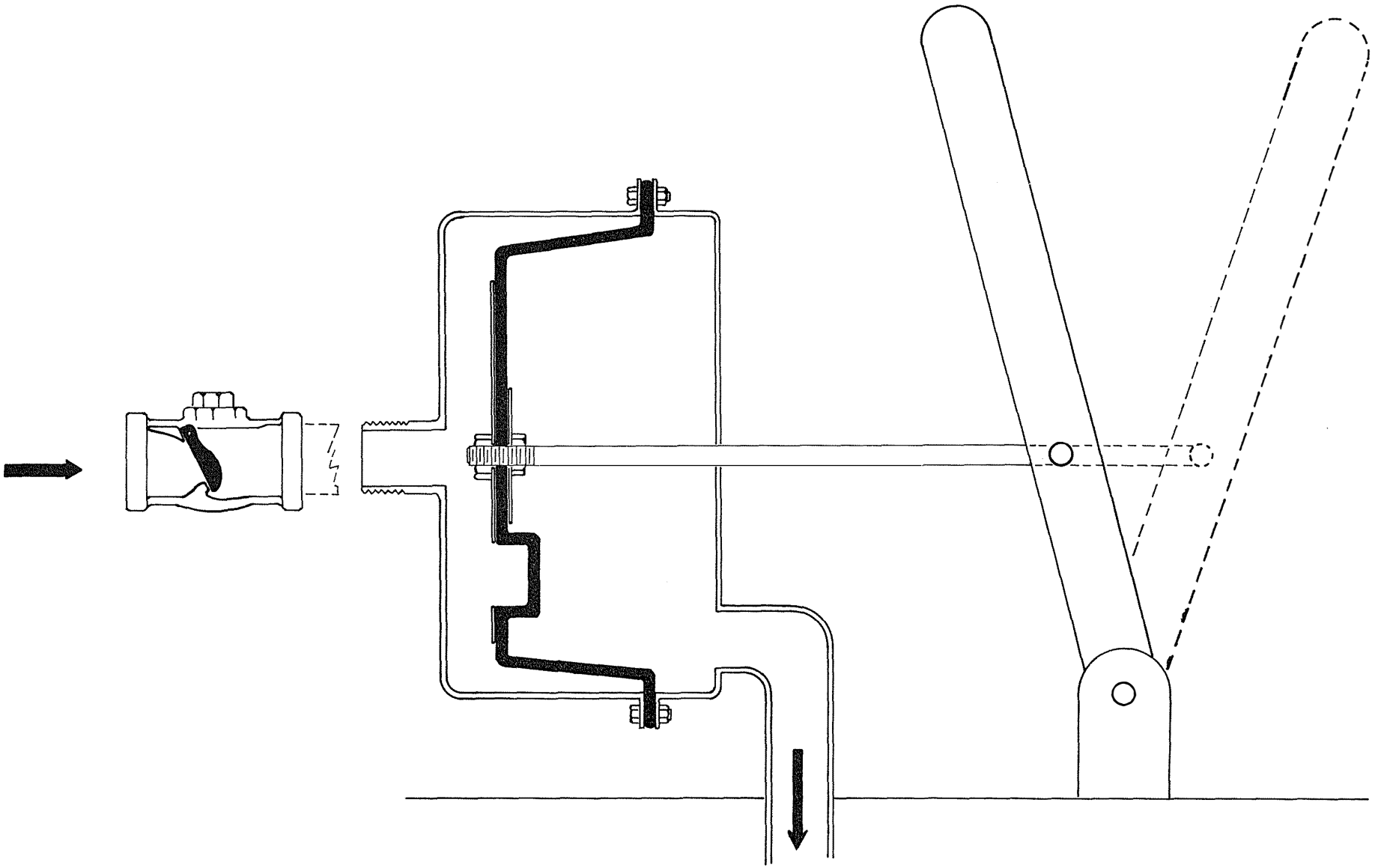
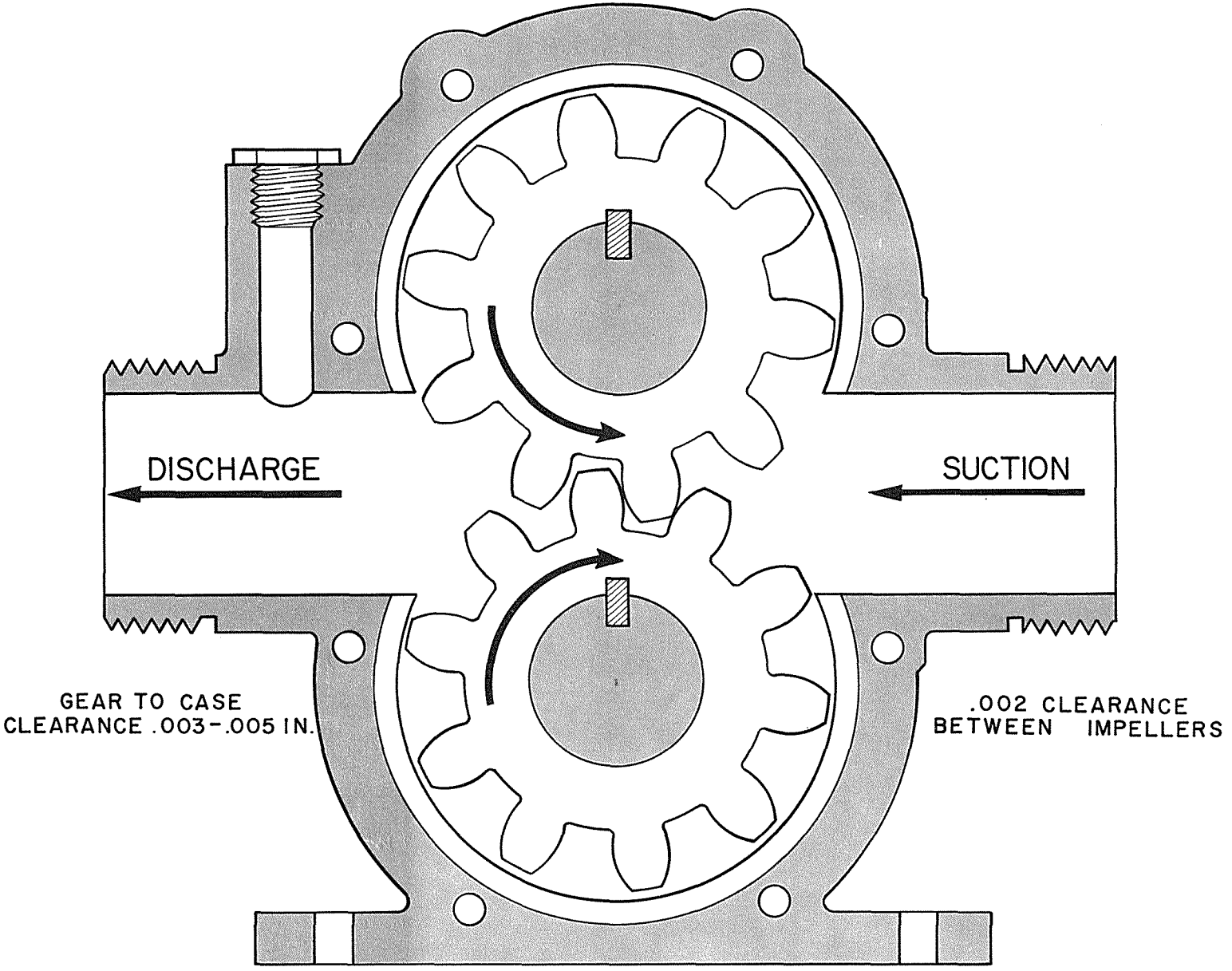
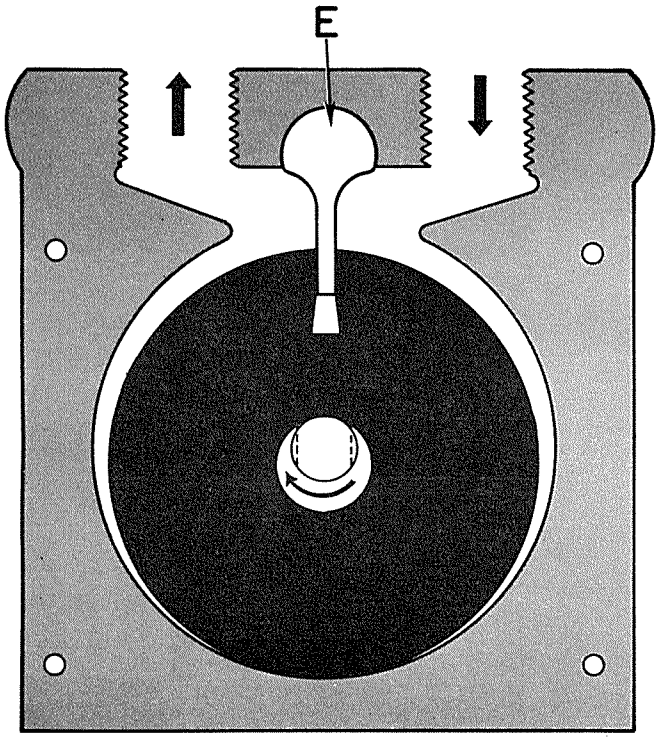
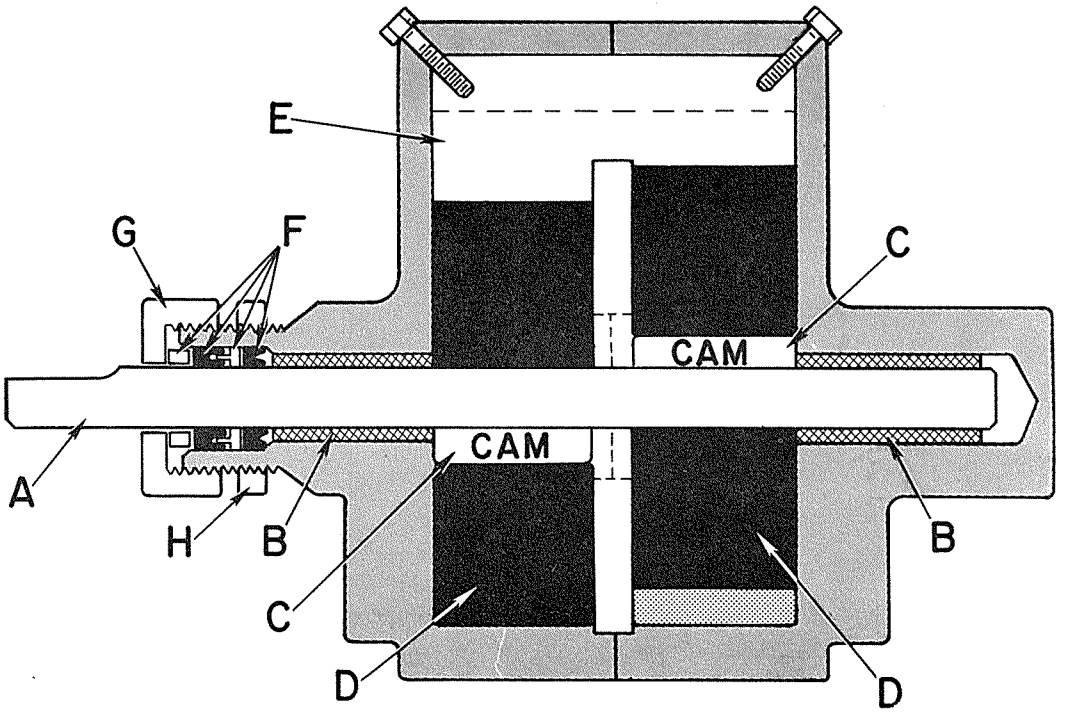


FIG. 3-A

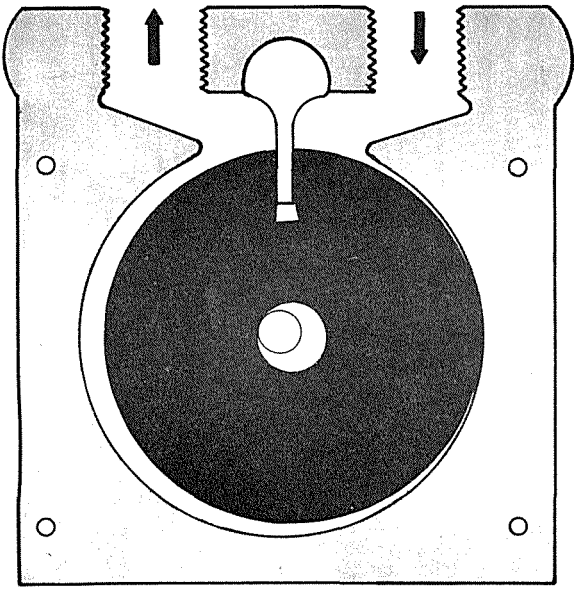


TYPICAL GEAR PUMP
FIGURE 4

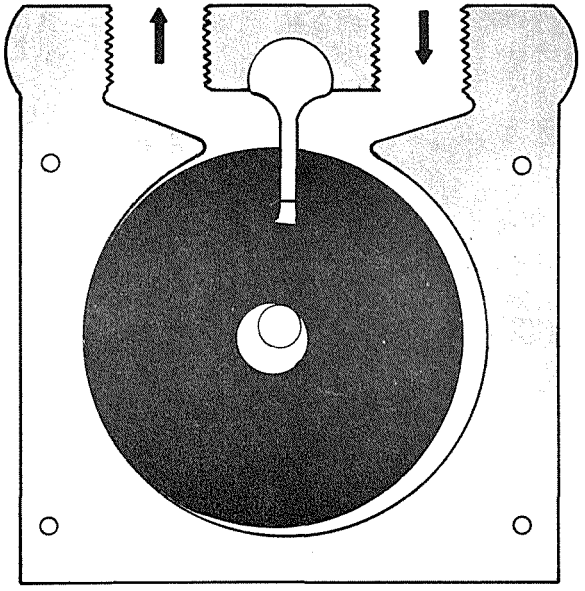




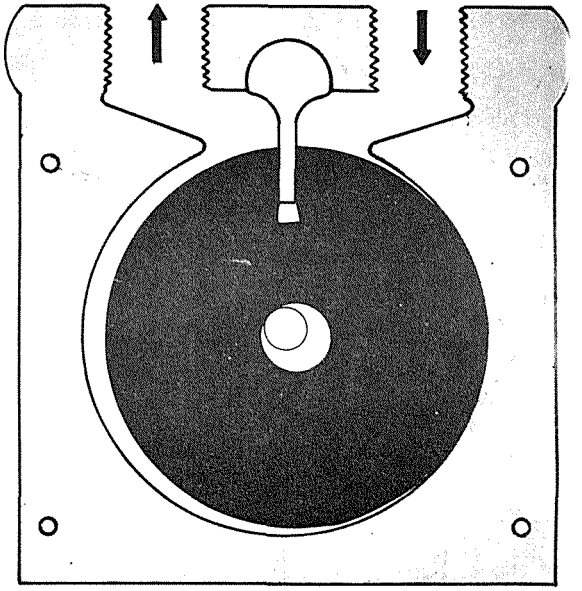
ECO PUMP-PARTS
FIGURE 5



A

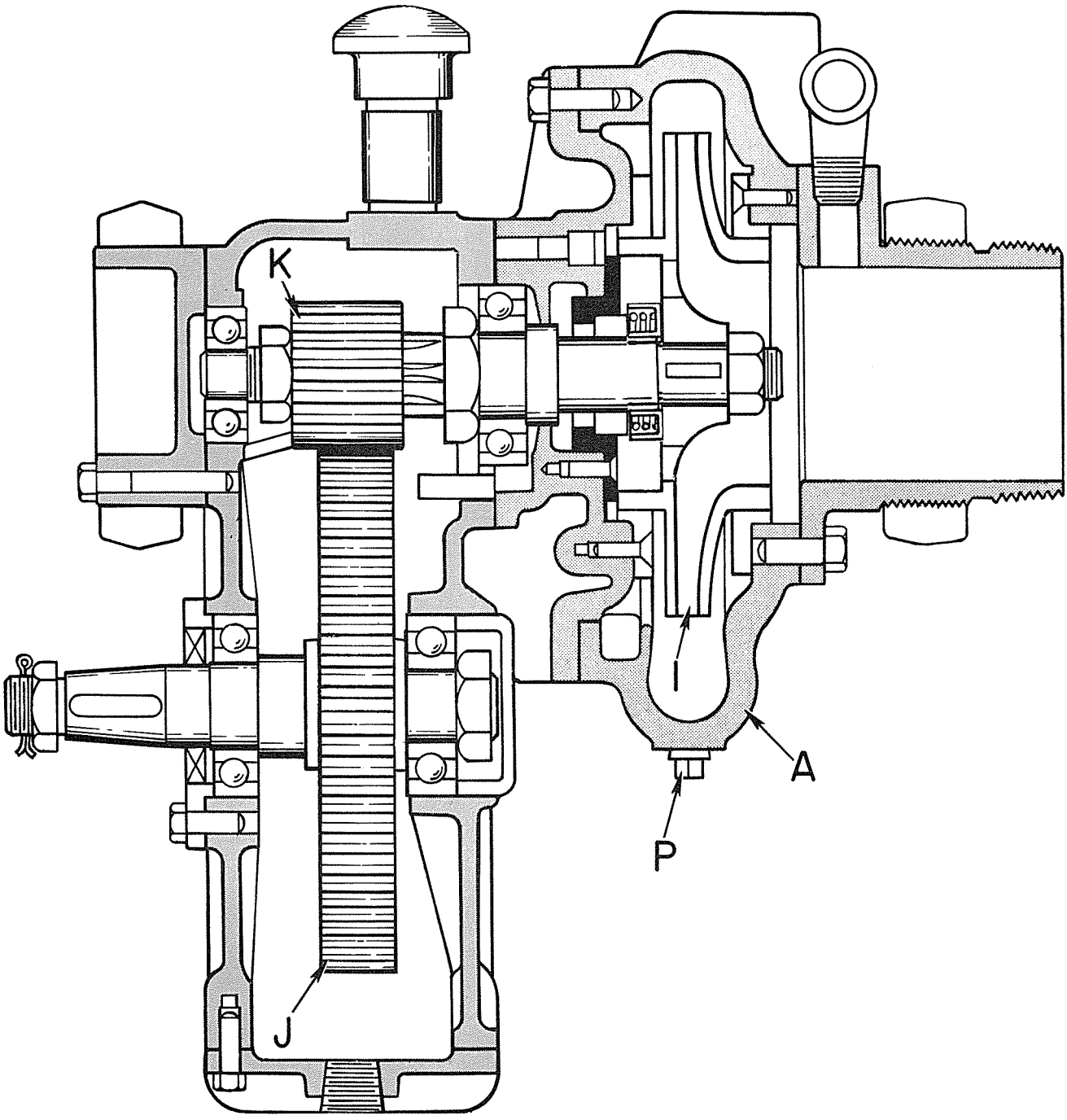


B



C

ECO PUMP OPERATION
FIGURE 6



SINGLE-STAGE CENTRIFUGAL PUMP
FIGURE 7

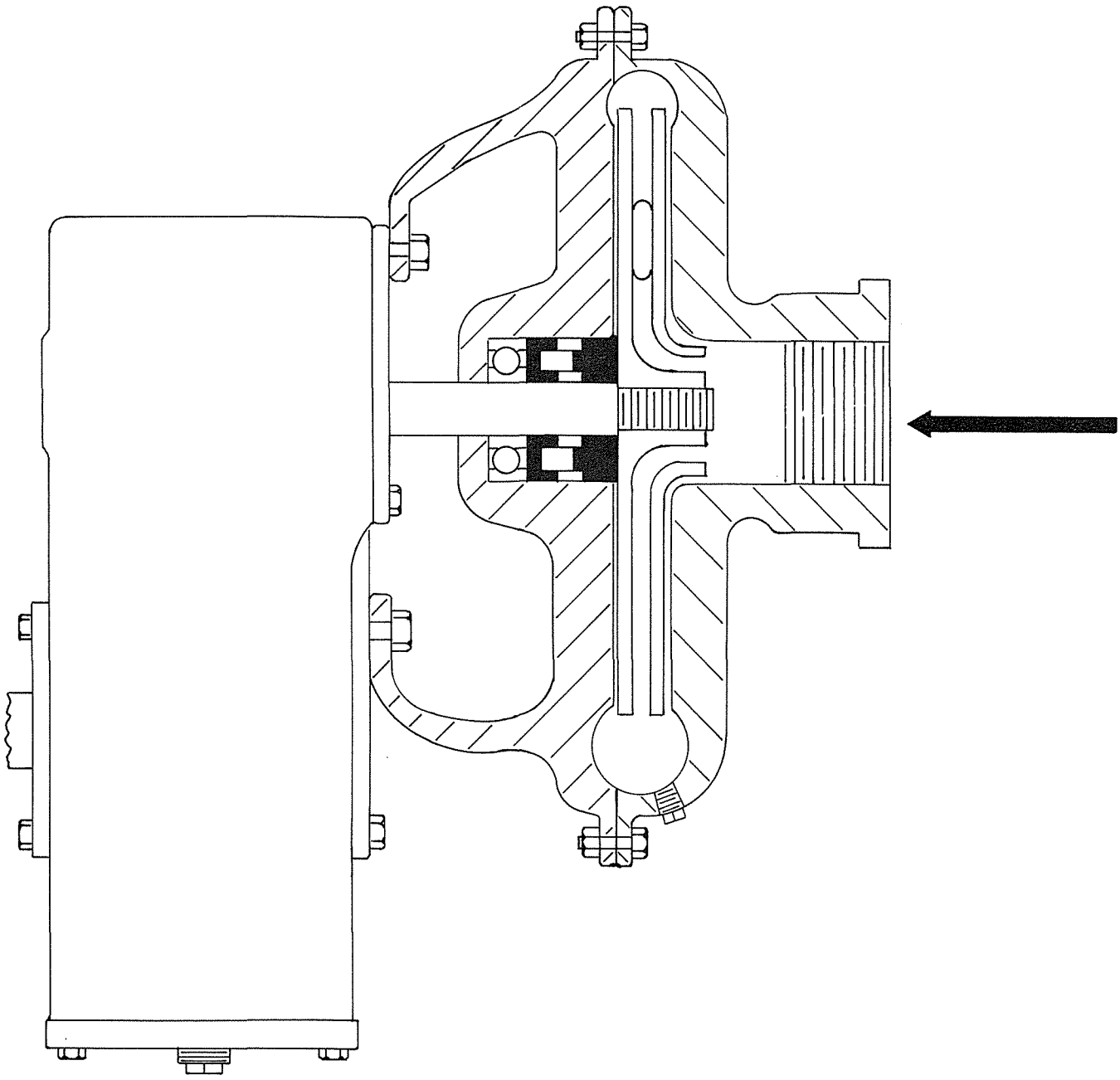
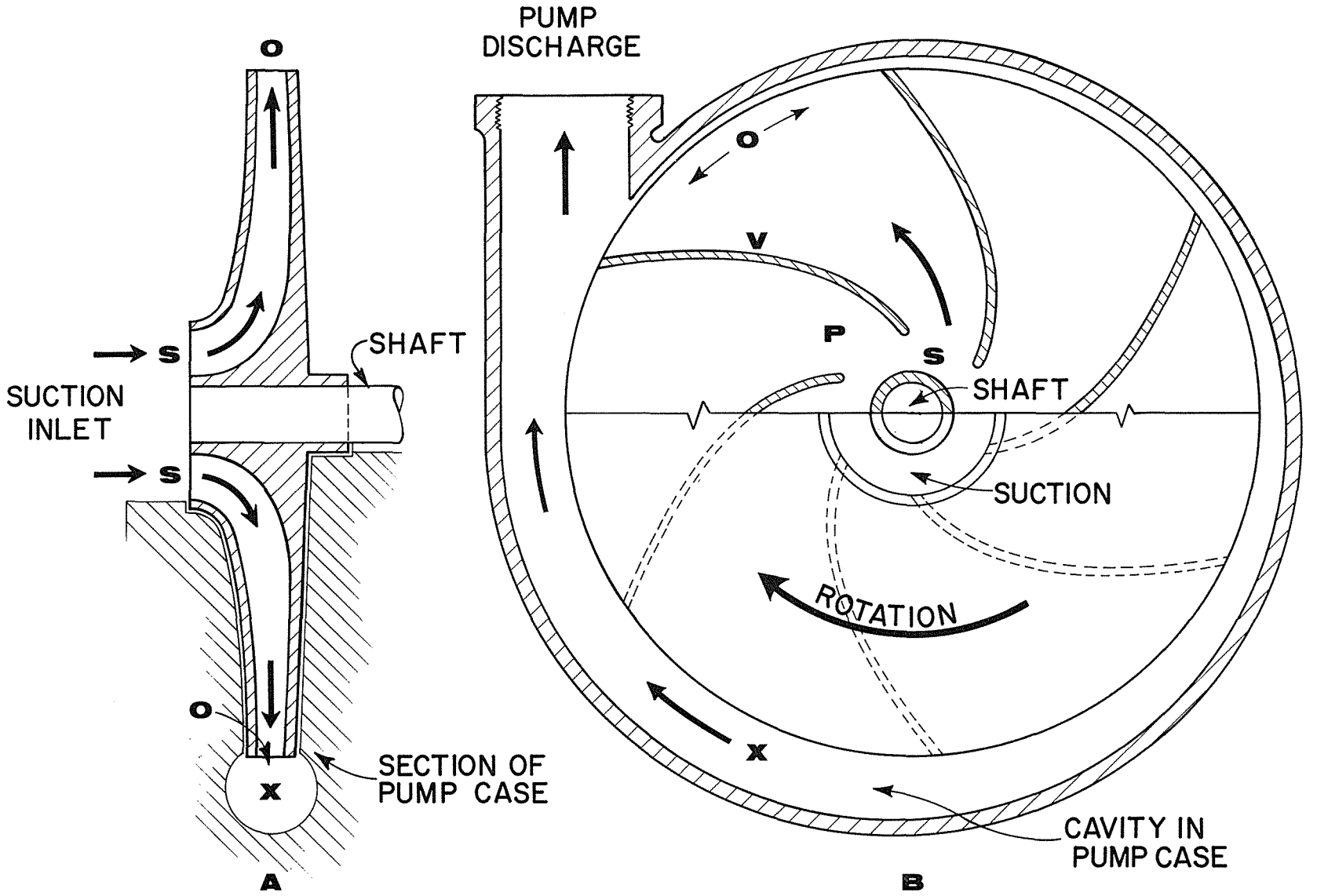
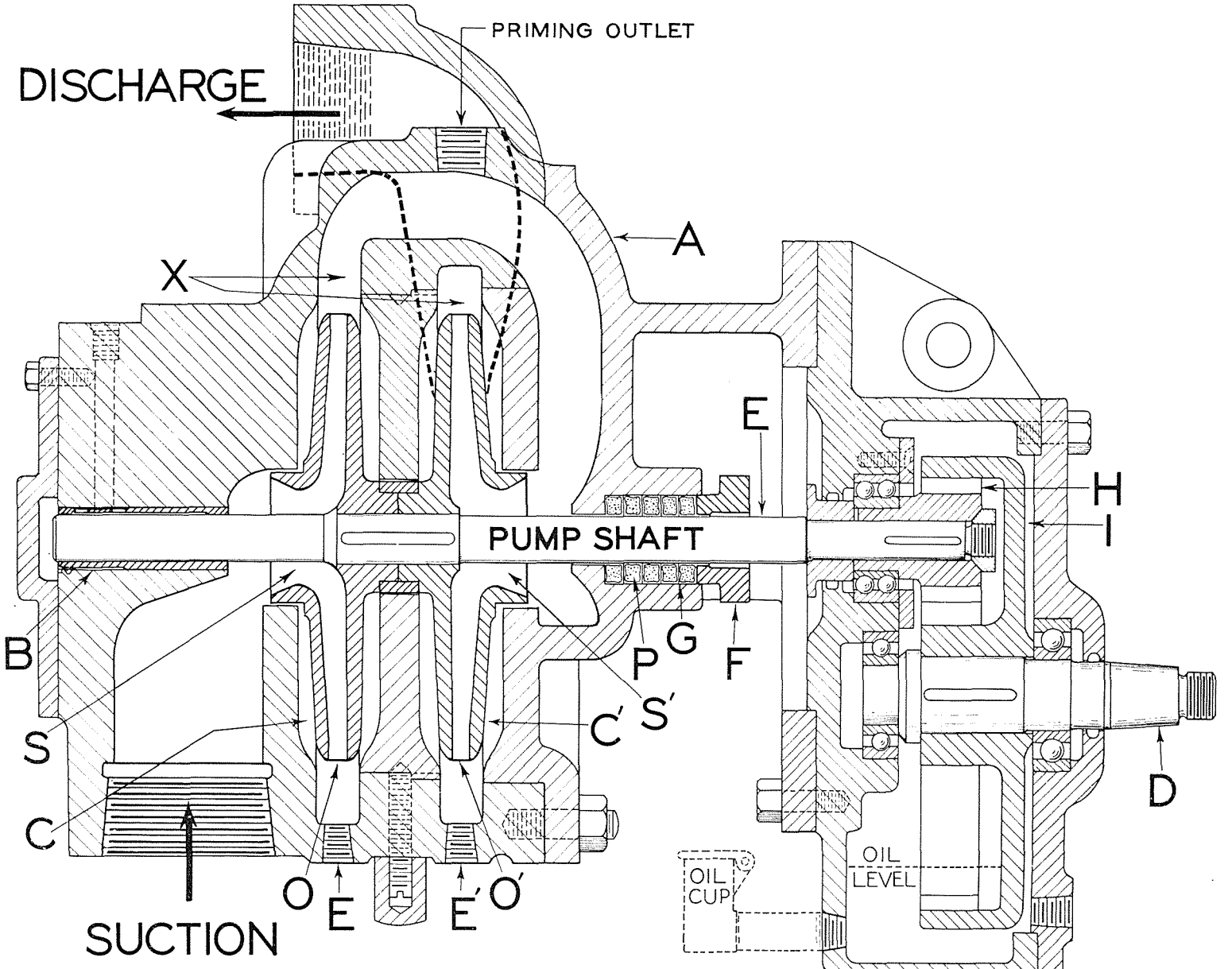


FIG. 7-A



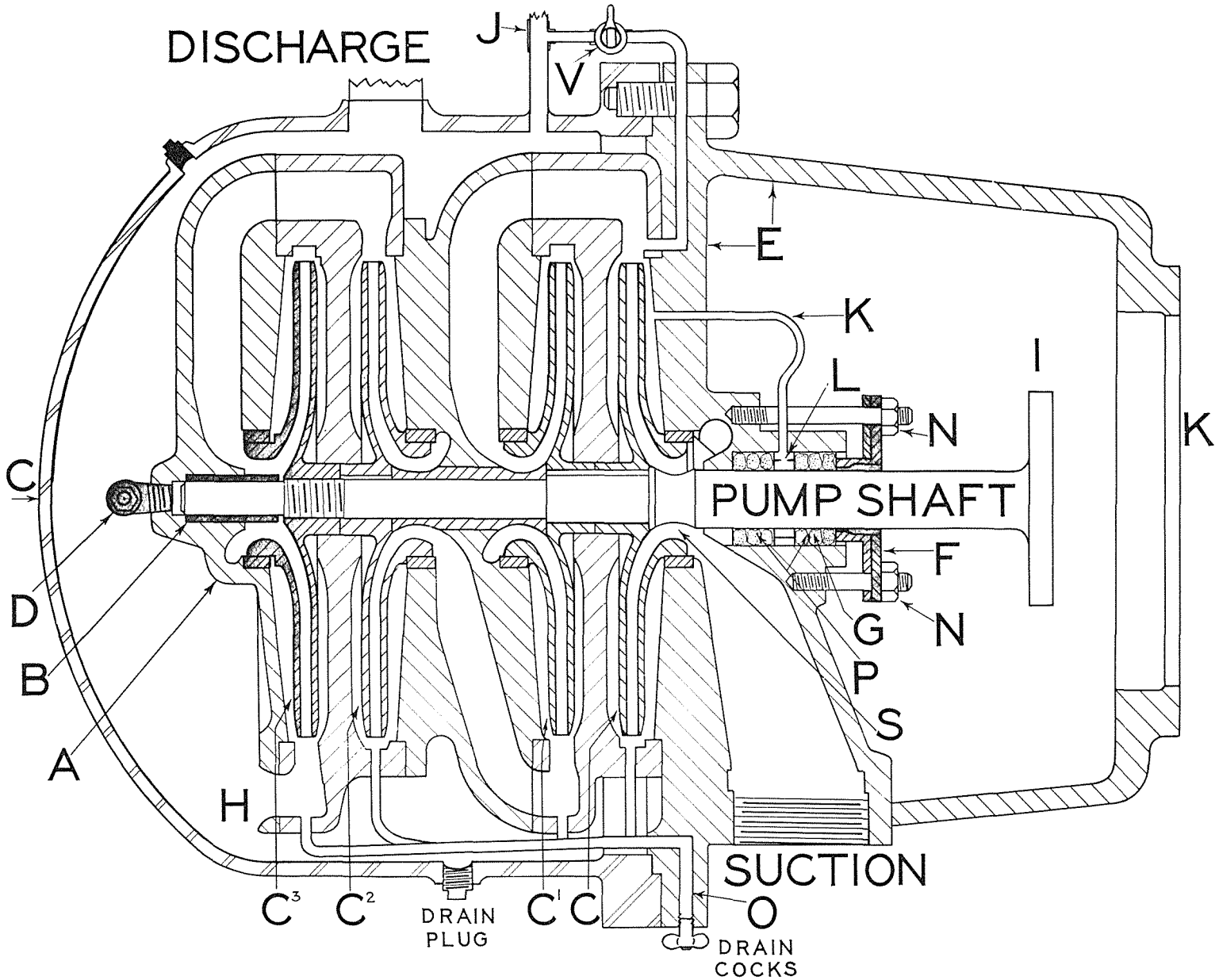
CLOSED TYPE IMPELLER FOR CENTRIFUGAL PUMPS

FIGURE 8



BYRON JACKSON 2 STAGE CENTRIFUGAL

FIG. 8C



BERKELEY 4 STAGE PUMP

FIG. 8D

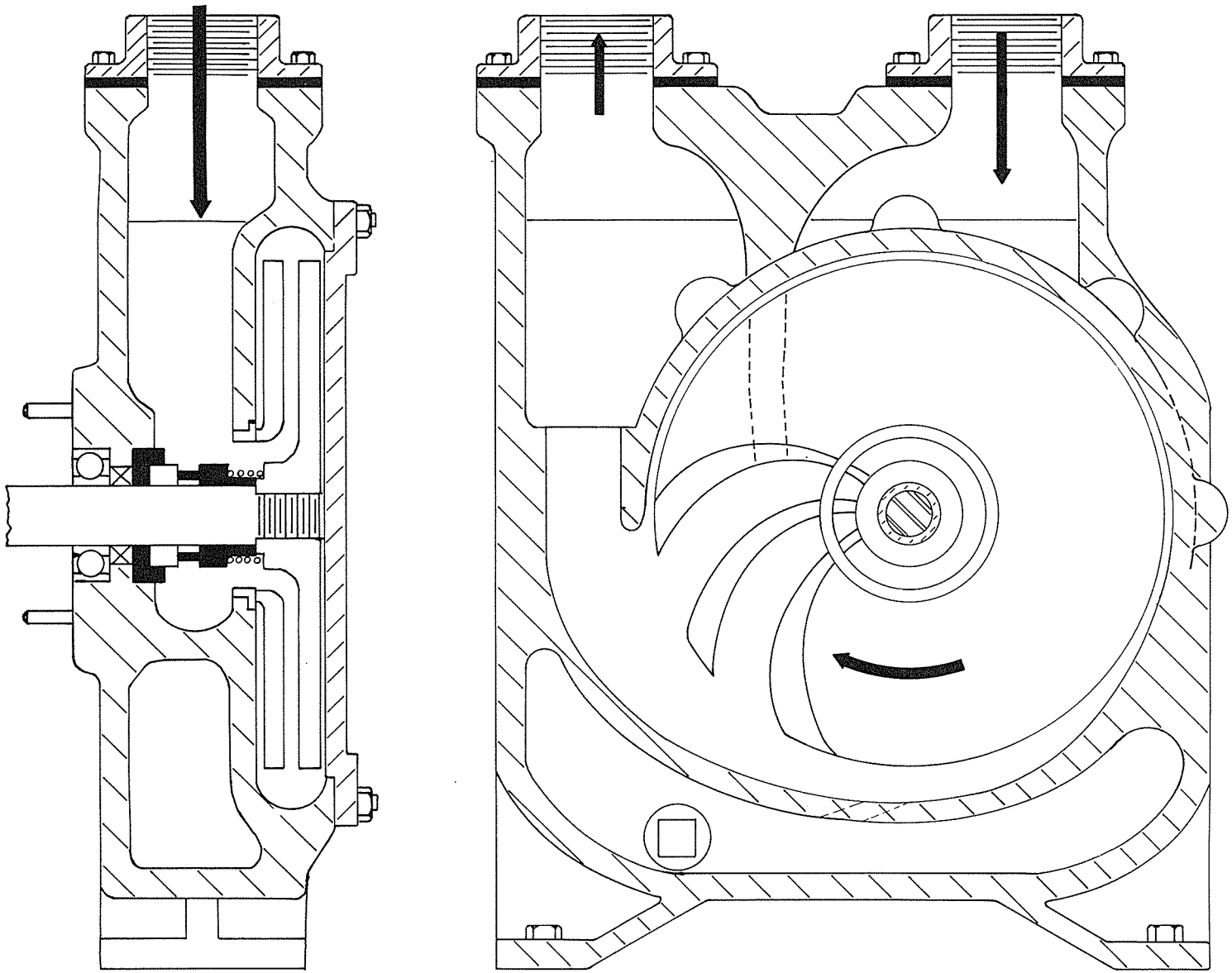
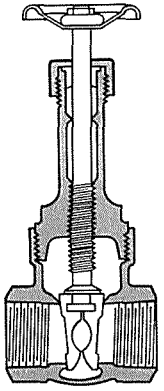


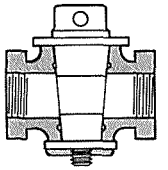
FIG. 8E

2



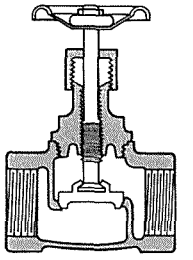
GATE VALVE

3



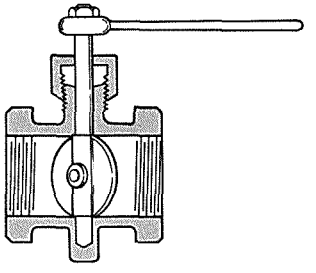
PLUG VALVE

1



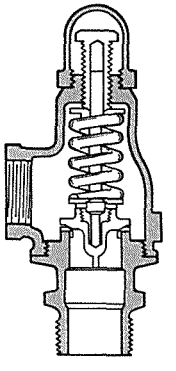
GLOBE VALVE

5



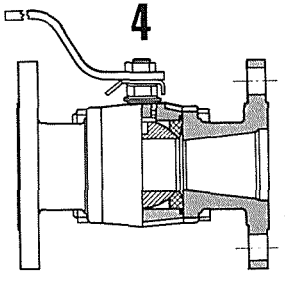
BUTTERFLY VALVE

6



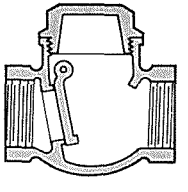
POPPET VALVE

4



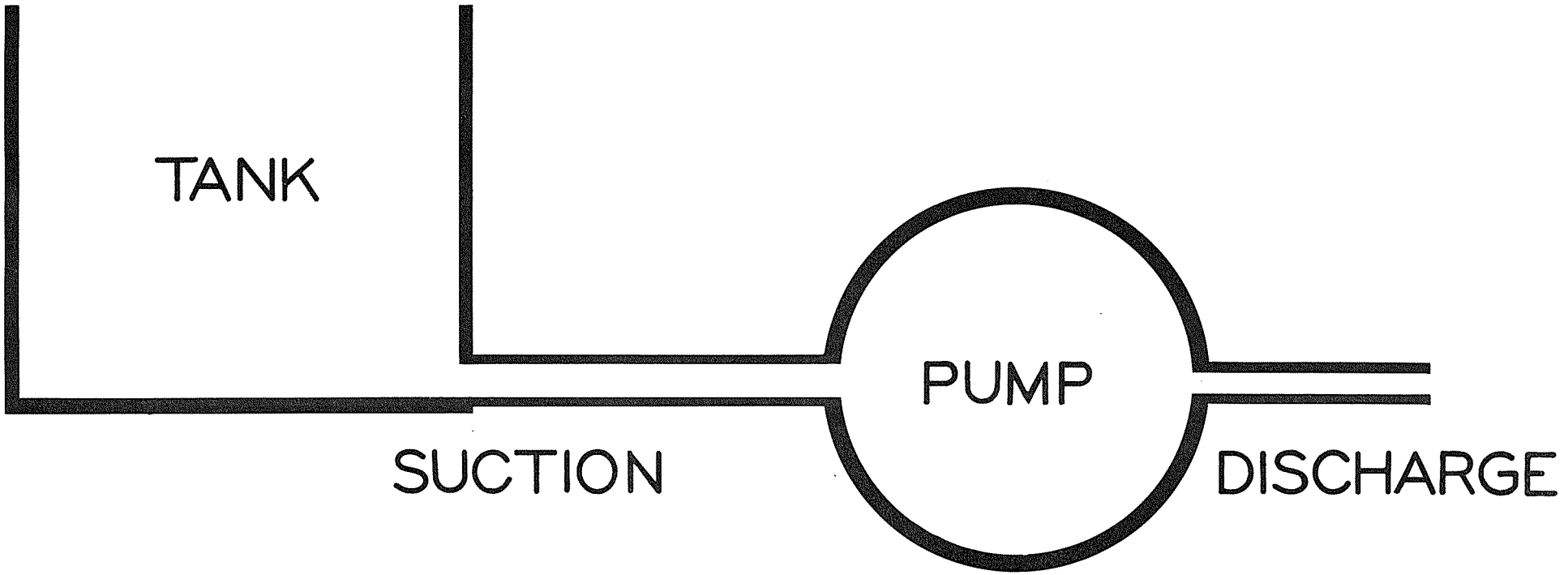
BALL VALVE

7



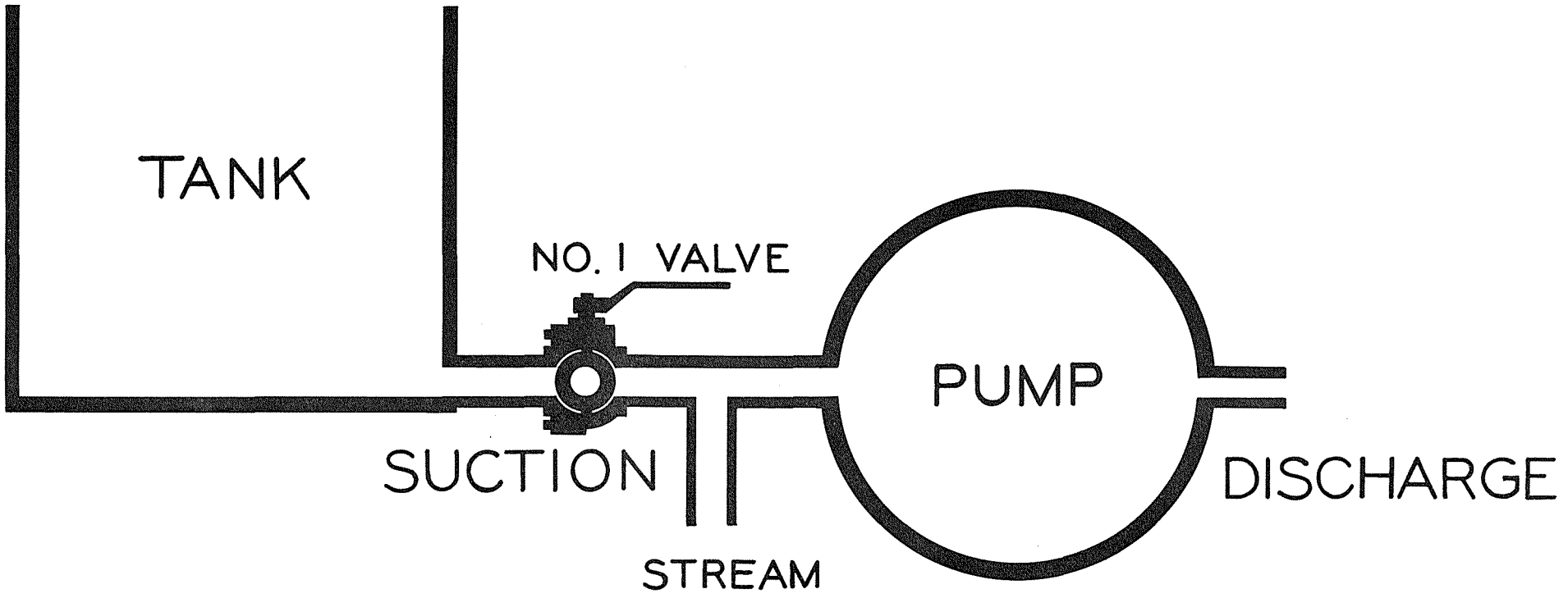
SWING CHECK VALVE

TYPICAL VALVES
FIGURE 9

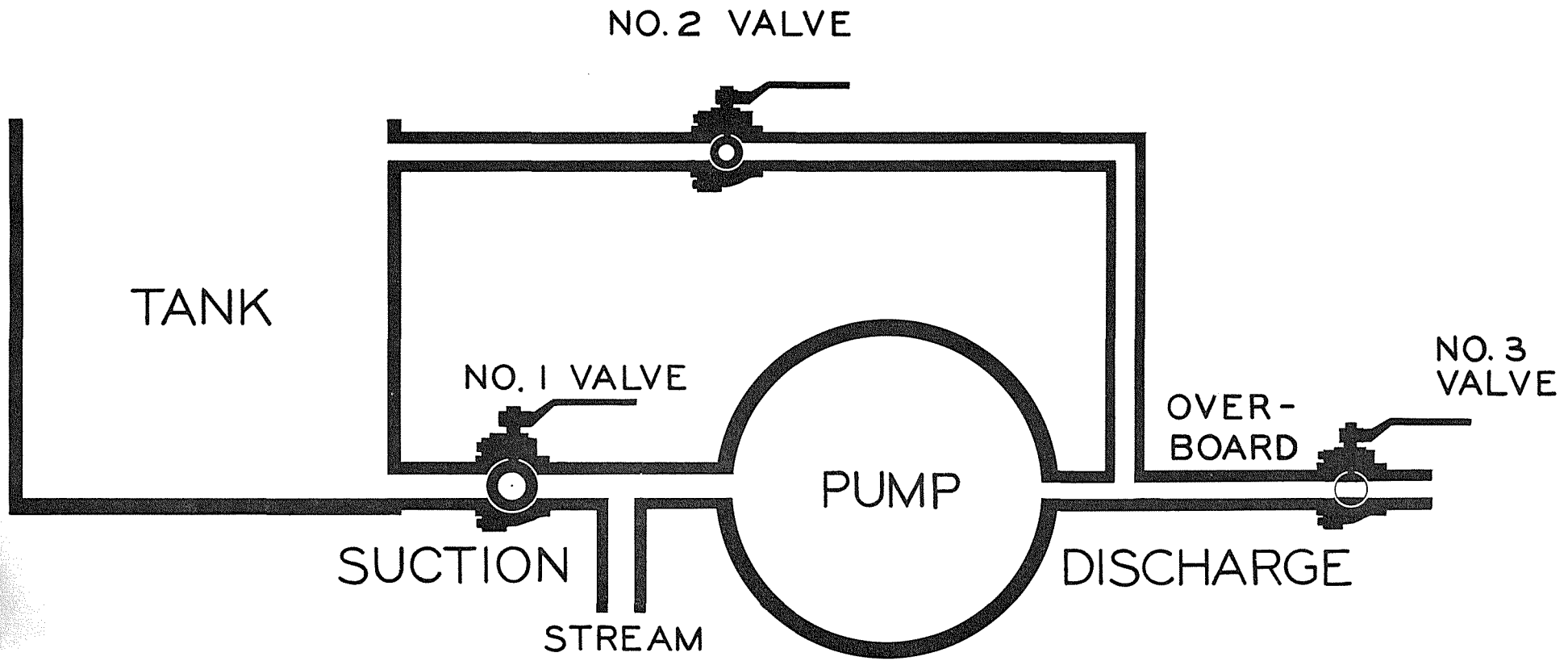


PIPING SYSTEM

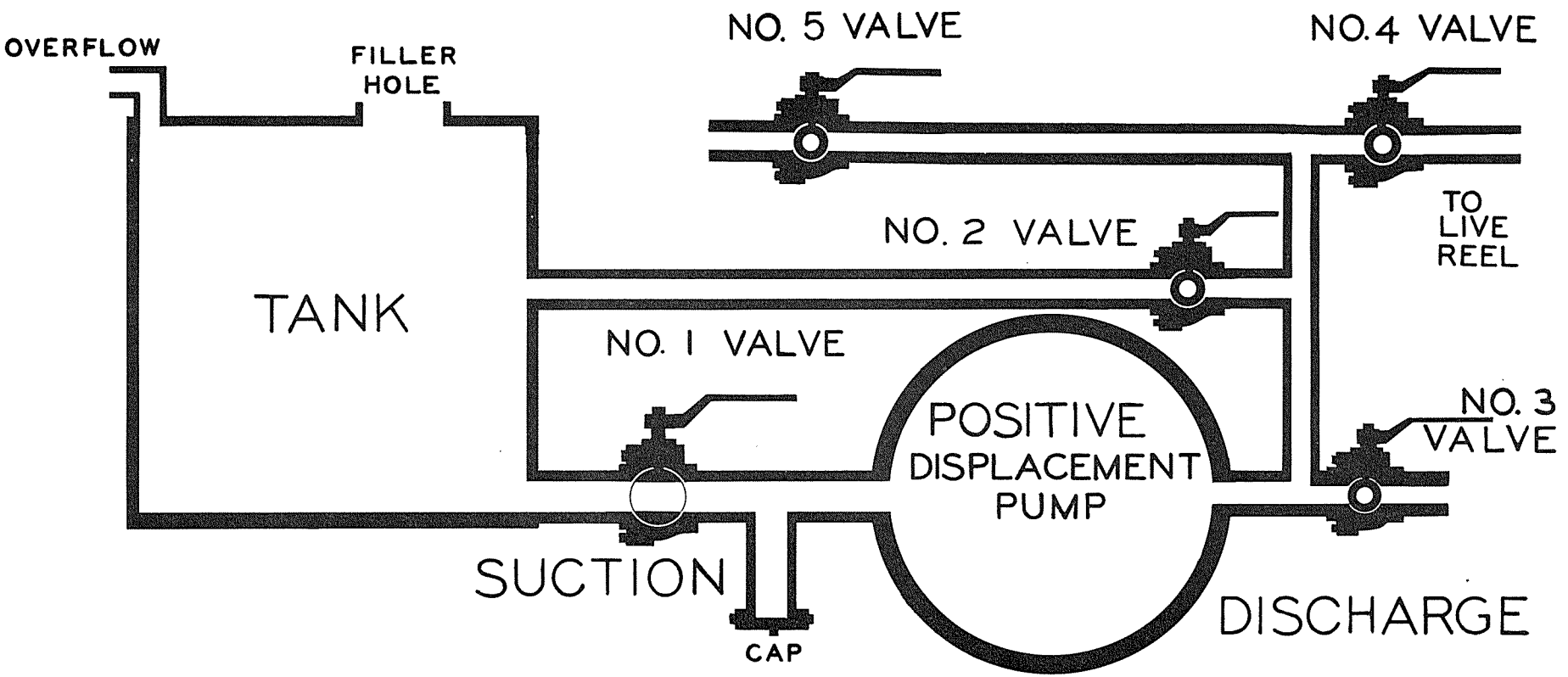
FIG.10



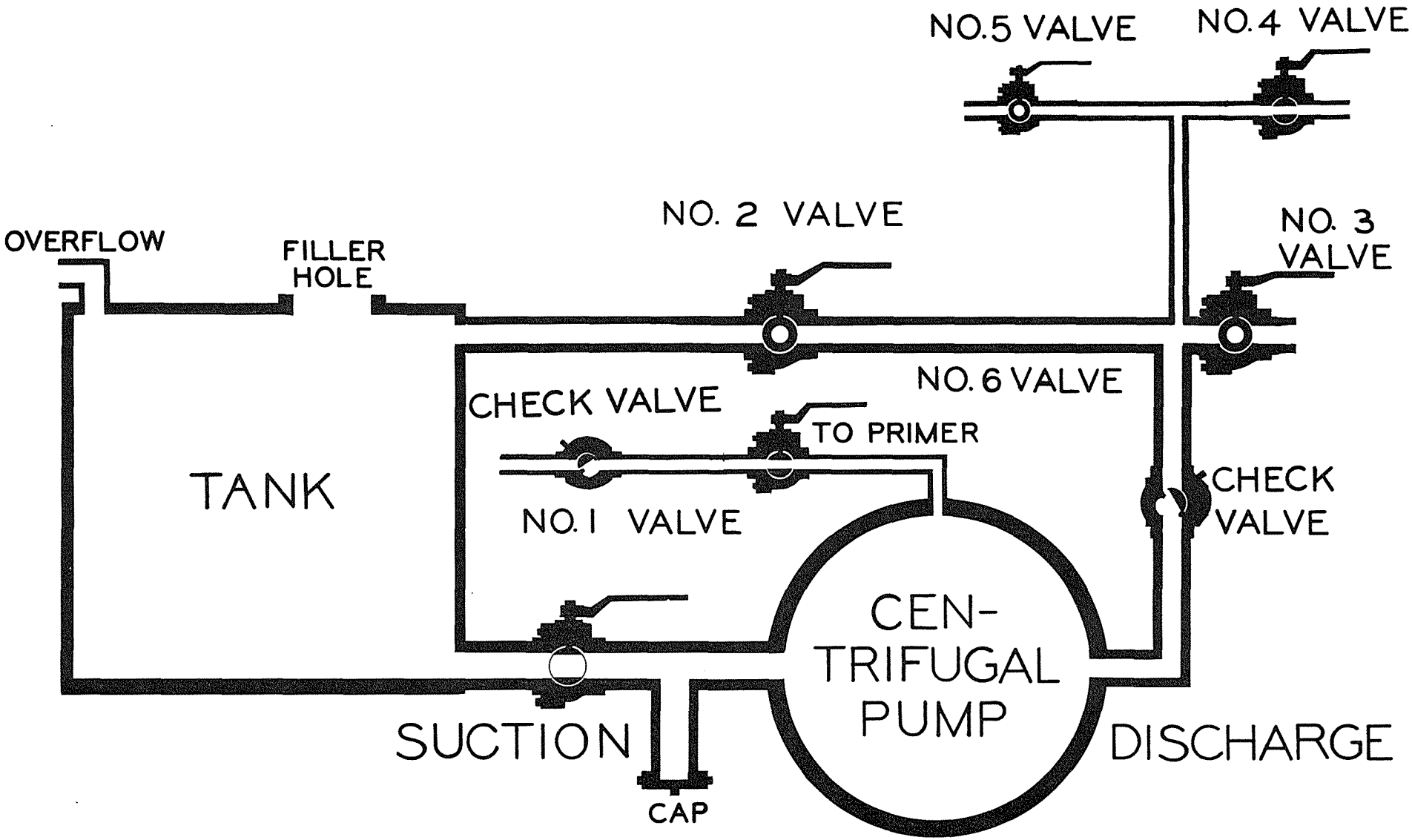
PIPING SYSTEM
FIG. 11



PIPING SYSTEM
FIG. 12



PIPING SYSTEM
FIG. 13



PIPING SYSTEM
FIG. 14

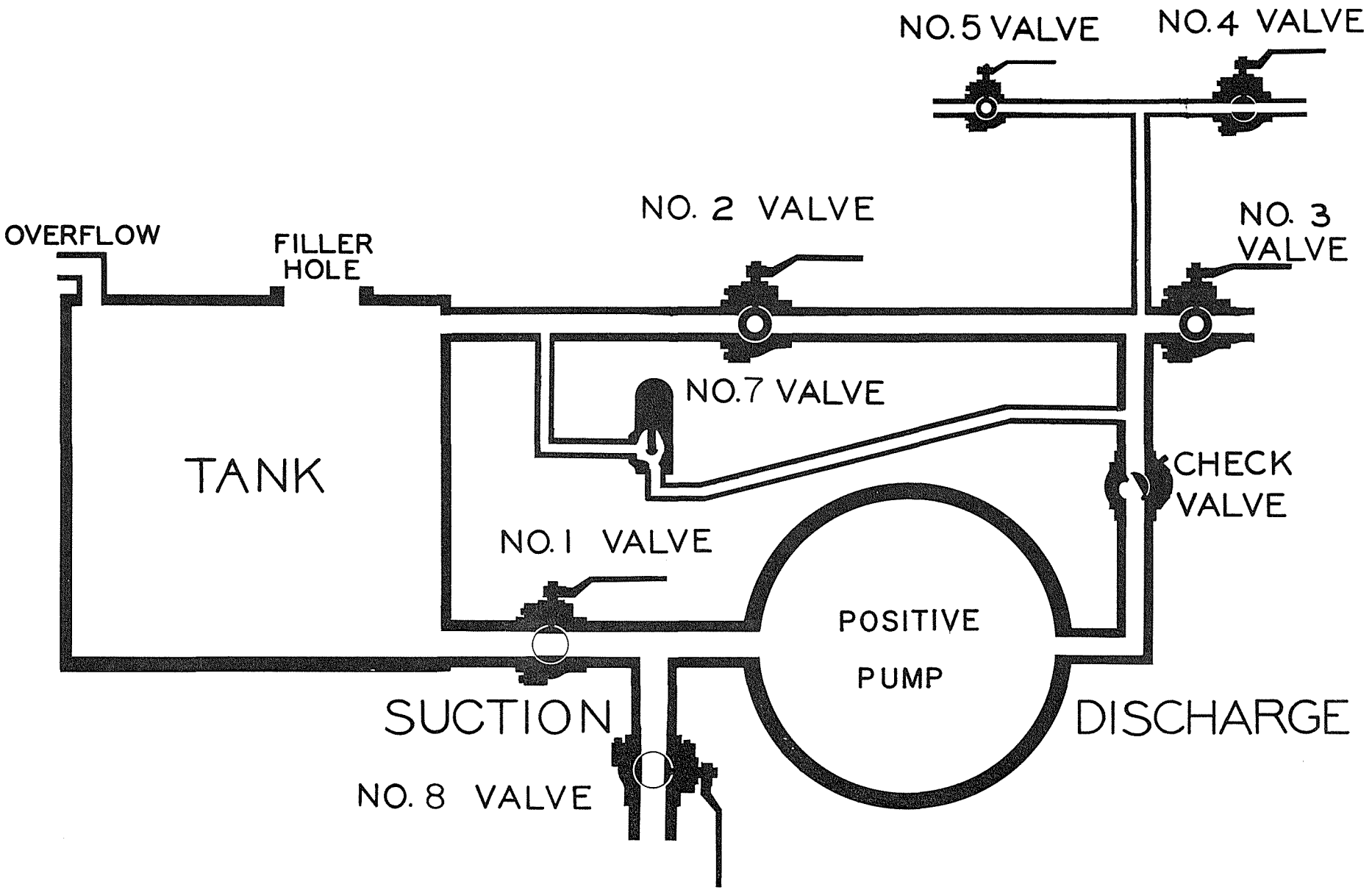

NO. 5 VALVE
NO. 4 VALVE
NO. 2 VALVE
NO. 3 VALVE
OVERFLOW
FILLER HOLE
NO. 7 VALVE
TANK
CHECK VALVE
NO. 1 VALVE
POSITIVE PUMP
SUCTION
DISCHARGE
NO. 8 VALVE
PIPING SYSTEM

FIG. 14-A

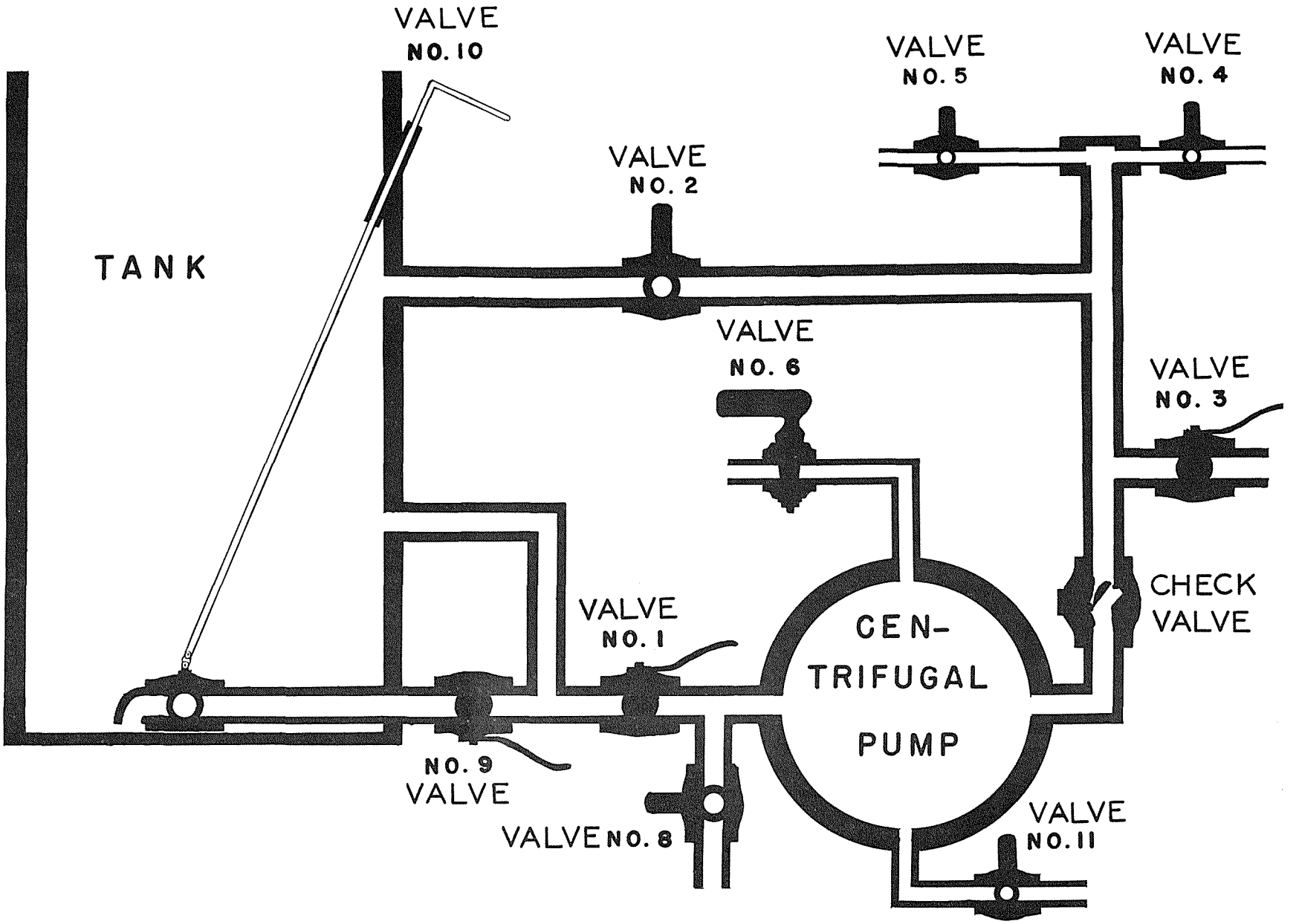

VALVE
NO. 10
VALVE
NO. 5
VALVE
NO. 4
VALVE
NO. 2
TANK
VALVE
NO. 6
VALVE
NO. 3
CHECK
VALVE
VALVE
NO. 1
CEN-
TRIFUGAL
PUMP
NO. 9
VALVE
VALVE NO. 8
VALVE
NO. 11

FIG. 14-B

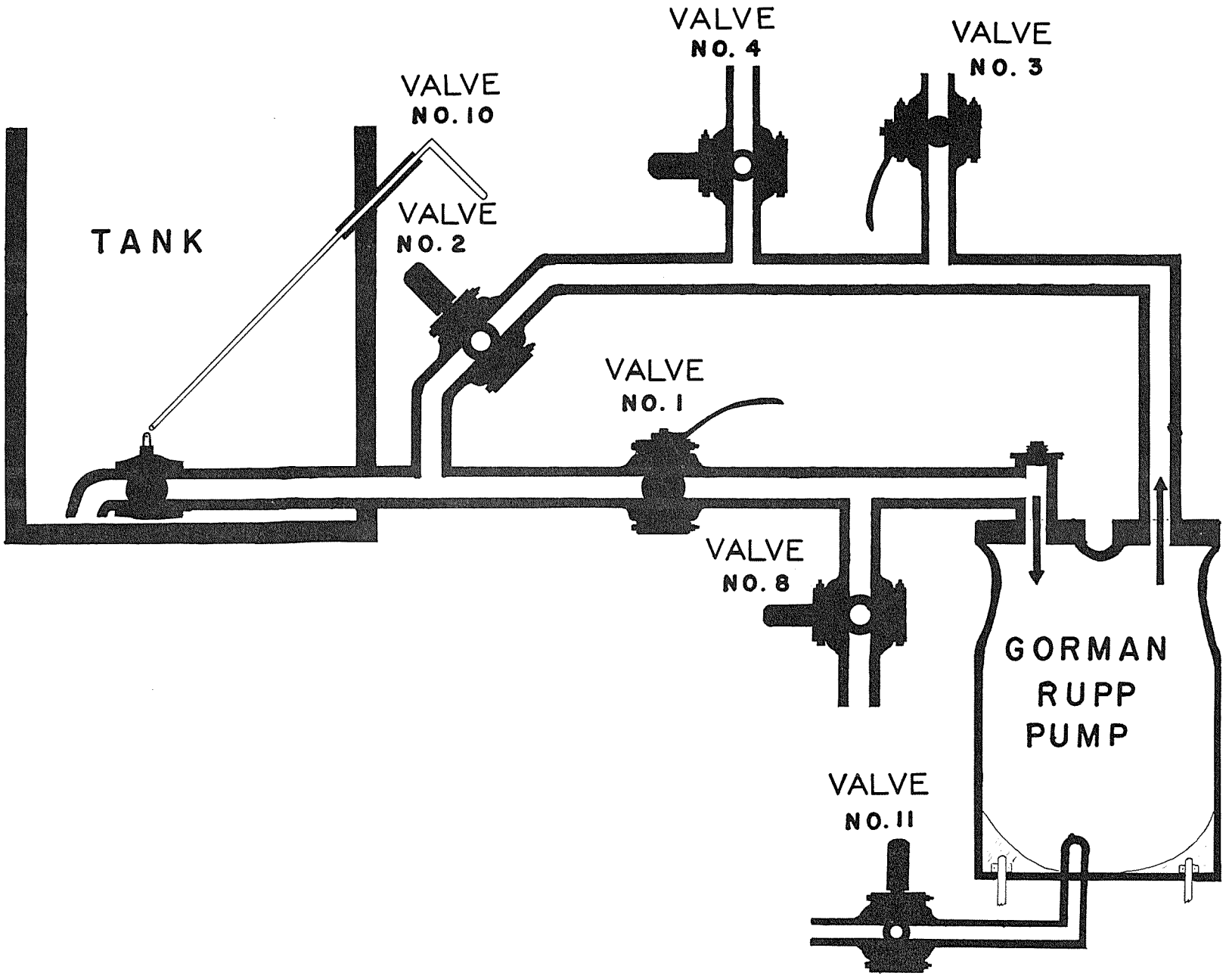
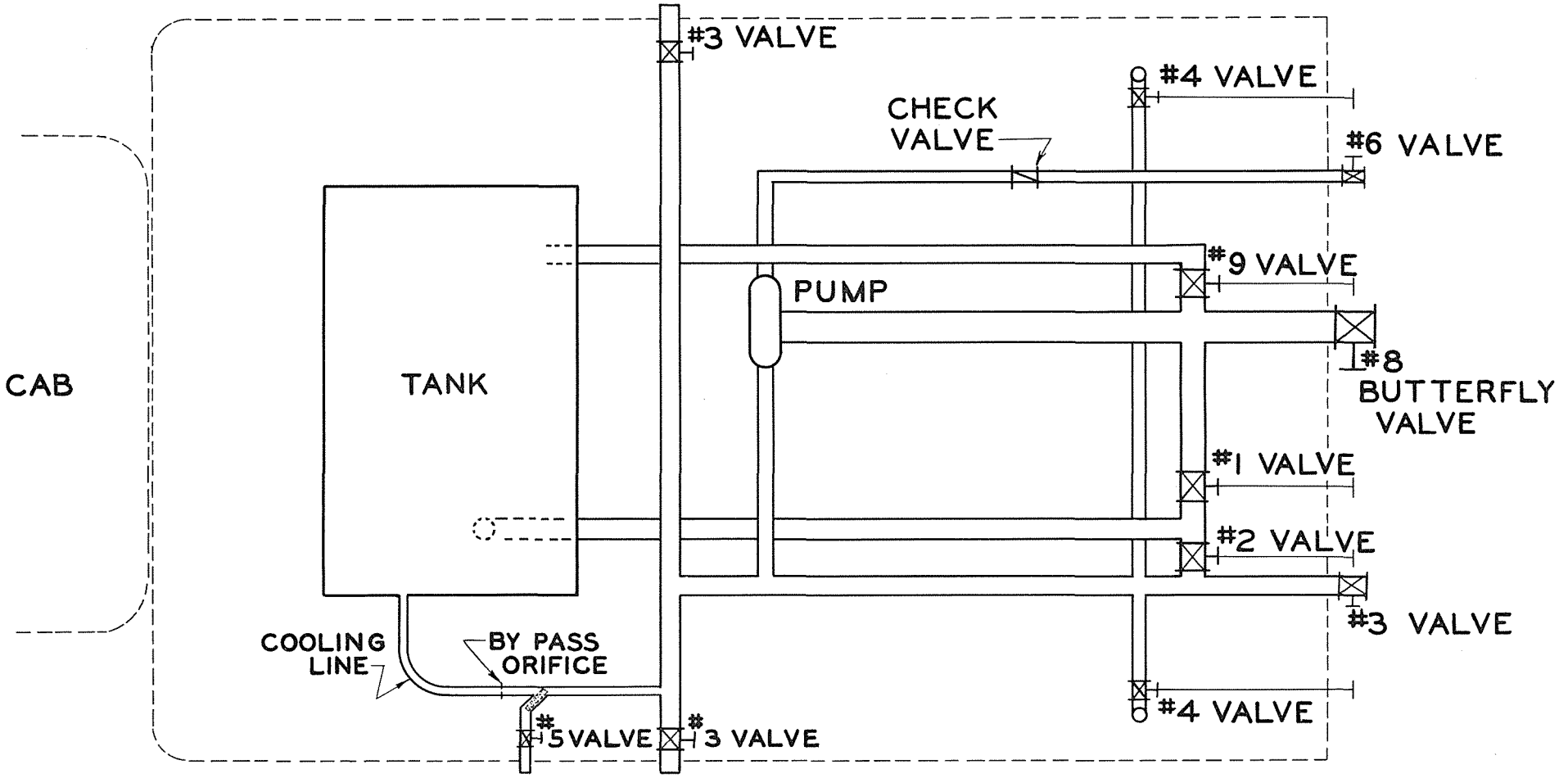
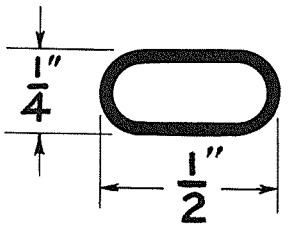

VALVE
NO. 4
VALVE
NO. 3
VALVE
NO. 10
TANK
VALVE
NO. 2
VALVE
NO. 1
VALVE
NO. 8
GORMAN
RUPP
PUMP
VALVE
NO. 11

FIG. 14-C

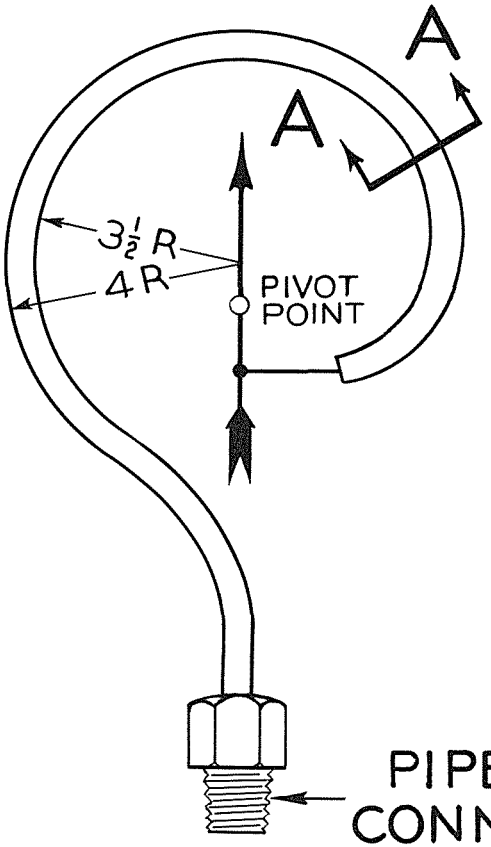


CLASS I TANKER PLUMBING SCHEMATIC

FIG. 15



SECTION A-A



PIPE THREAD
CONNECTION BLOCK

CIRCUMFERENCE = $2\pi R$

OUTSIDE CIRCUMFERENCE = 2 X 3.14 X4 = 25.12 IN.
INSIDE CIRCUMFERENCE = 2 X 3.14 X3.5 = 21.98 IN.

BOURDON TUBE PRESSURE GAUGE

FIG. 16

WATER EJECTOR

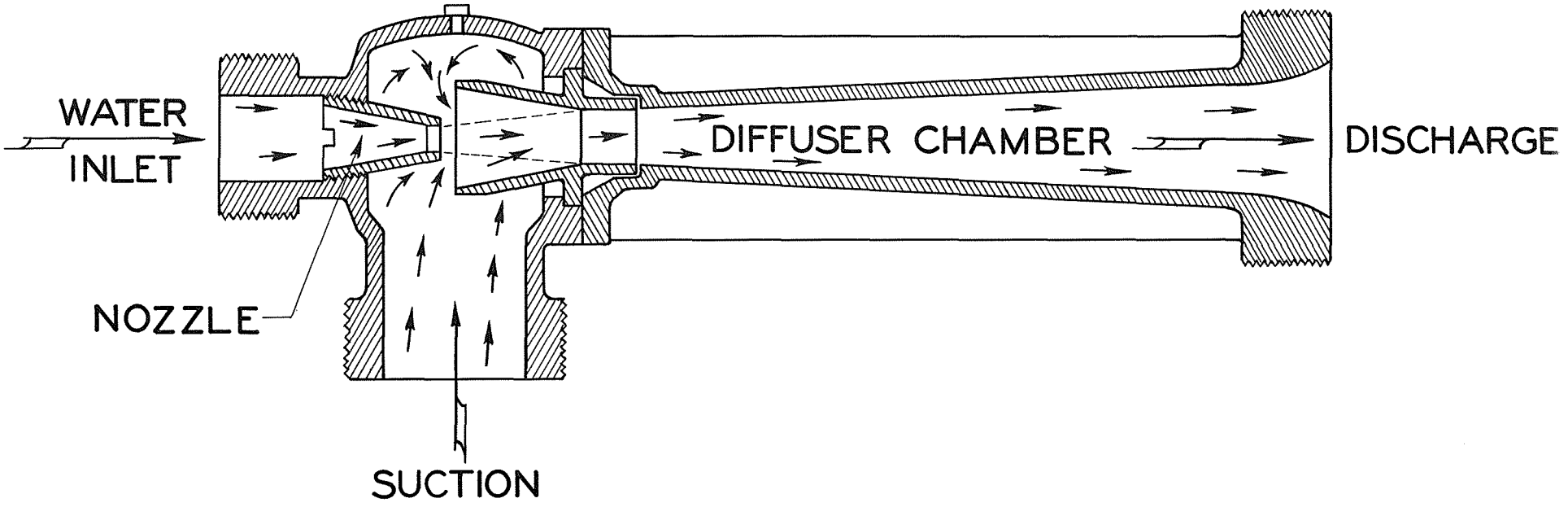


FIG. 17

WATER EJECTOR USE

U.S.F.S. – CALIFORNIA REGION

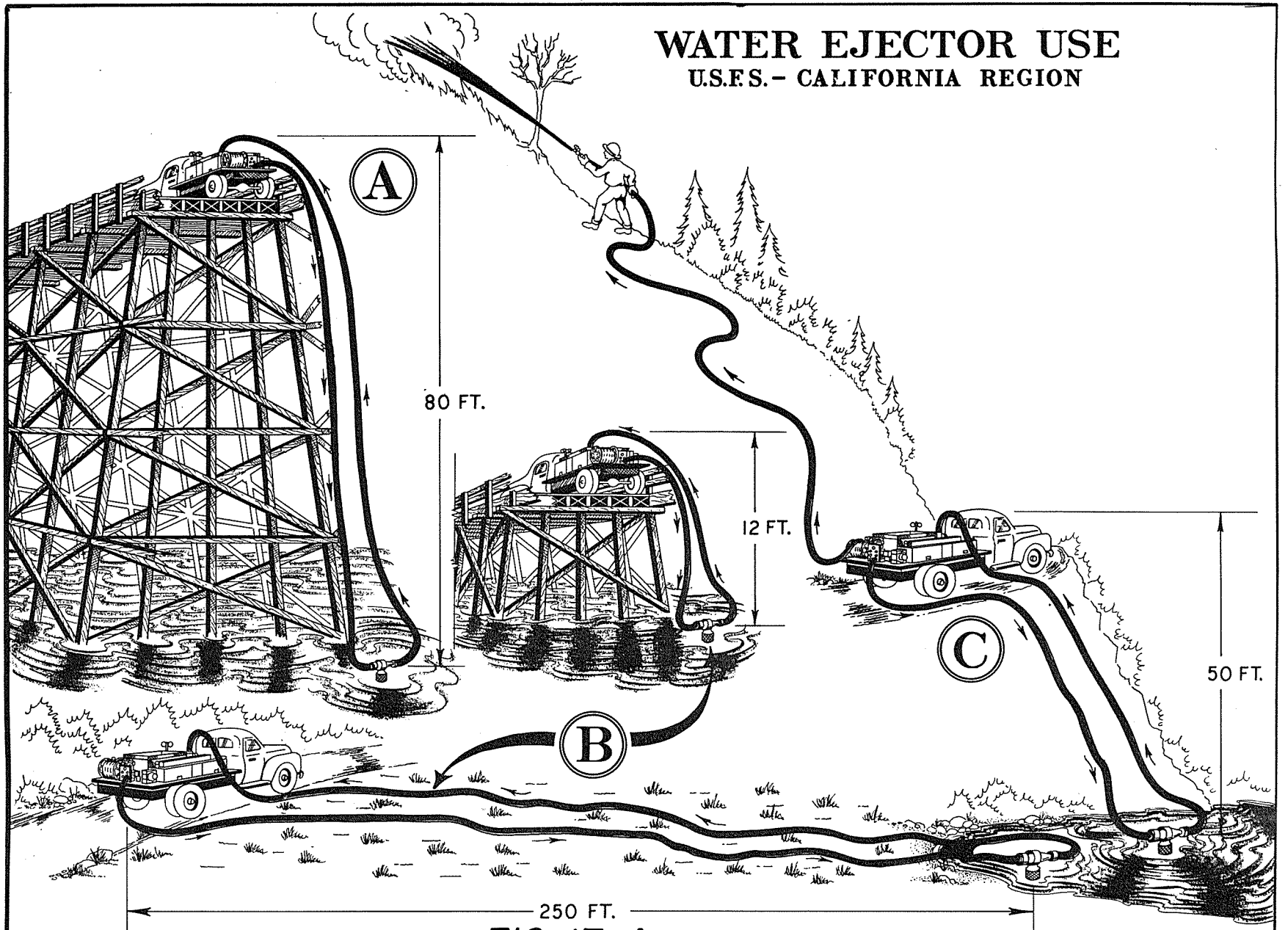


FIG. 17-A

PREPARED BY ARCADIA EQUIPMENT DEVELOPMENT CENTER–1953

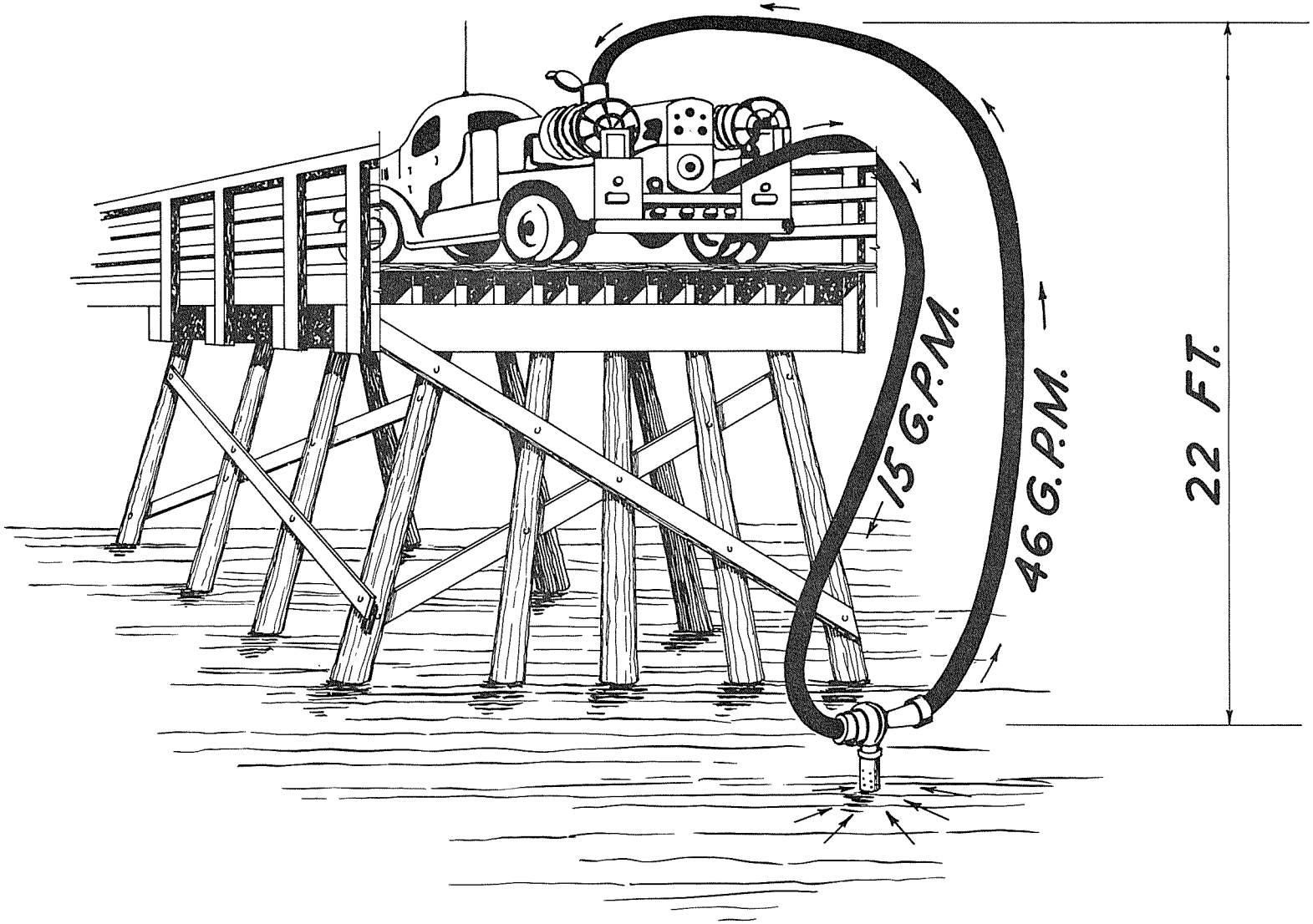


FIG. 17-B

DIRTY SAND LADEN WATER CAN BE UTILIZED TO PUT OUT FIRES AND UP TO 3 TIMES PUMPER CAPACITY CAN BE APPLIED SINCE NONE OF THE DIRTY WATER PASSES THROUGH THE PUMP.

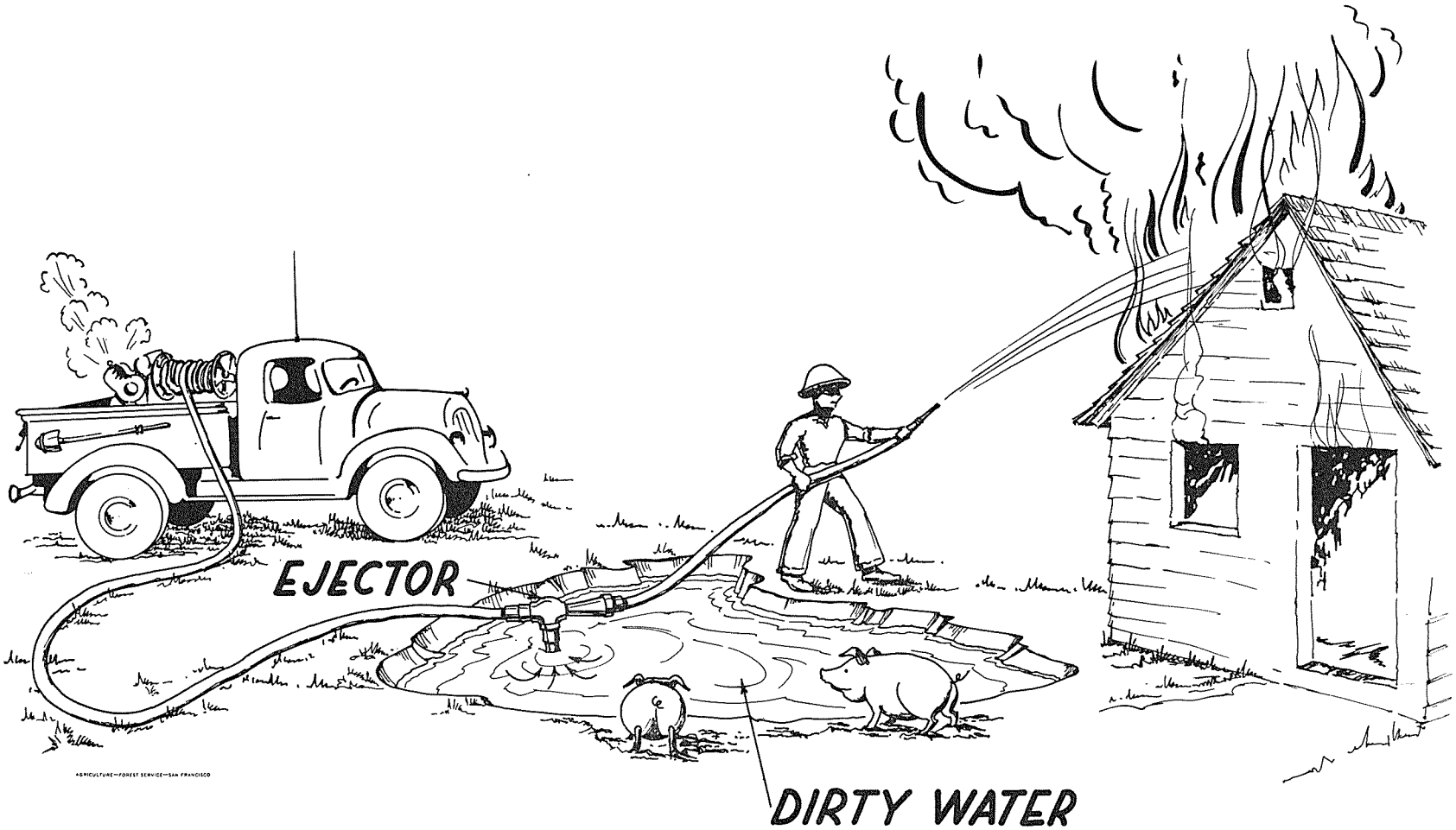
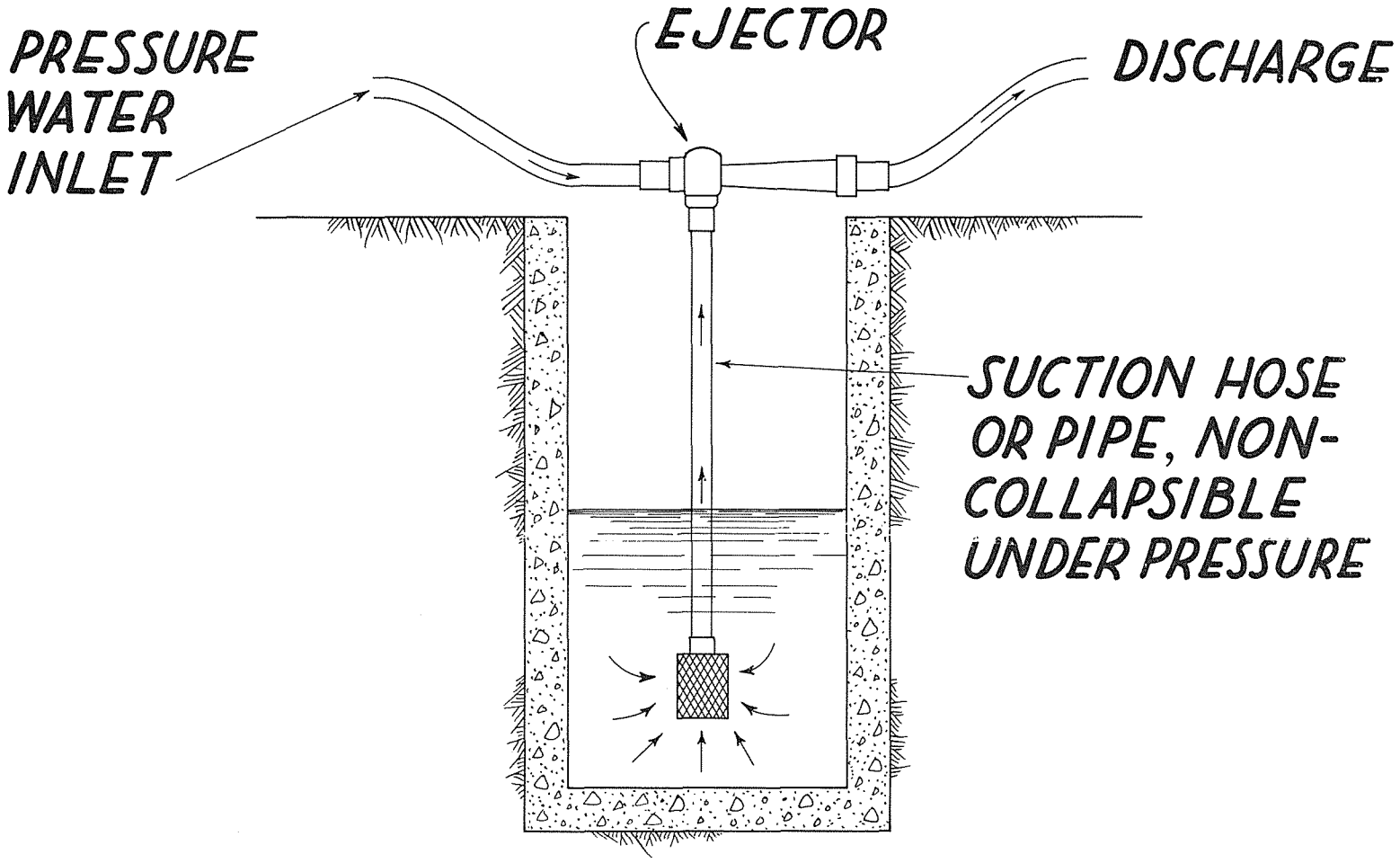
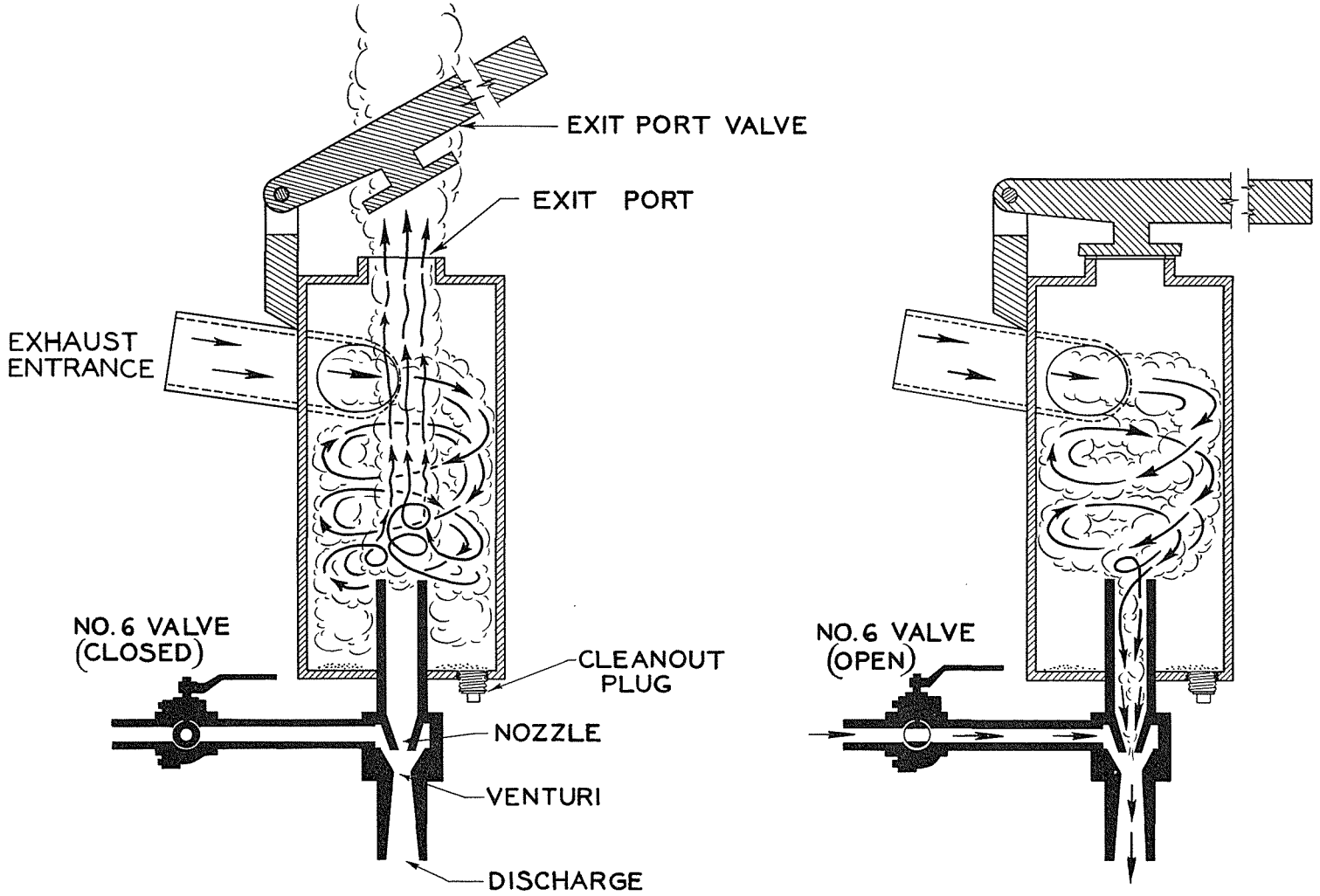


FIG. 17-C



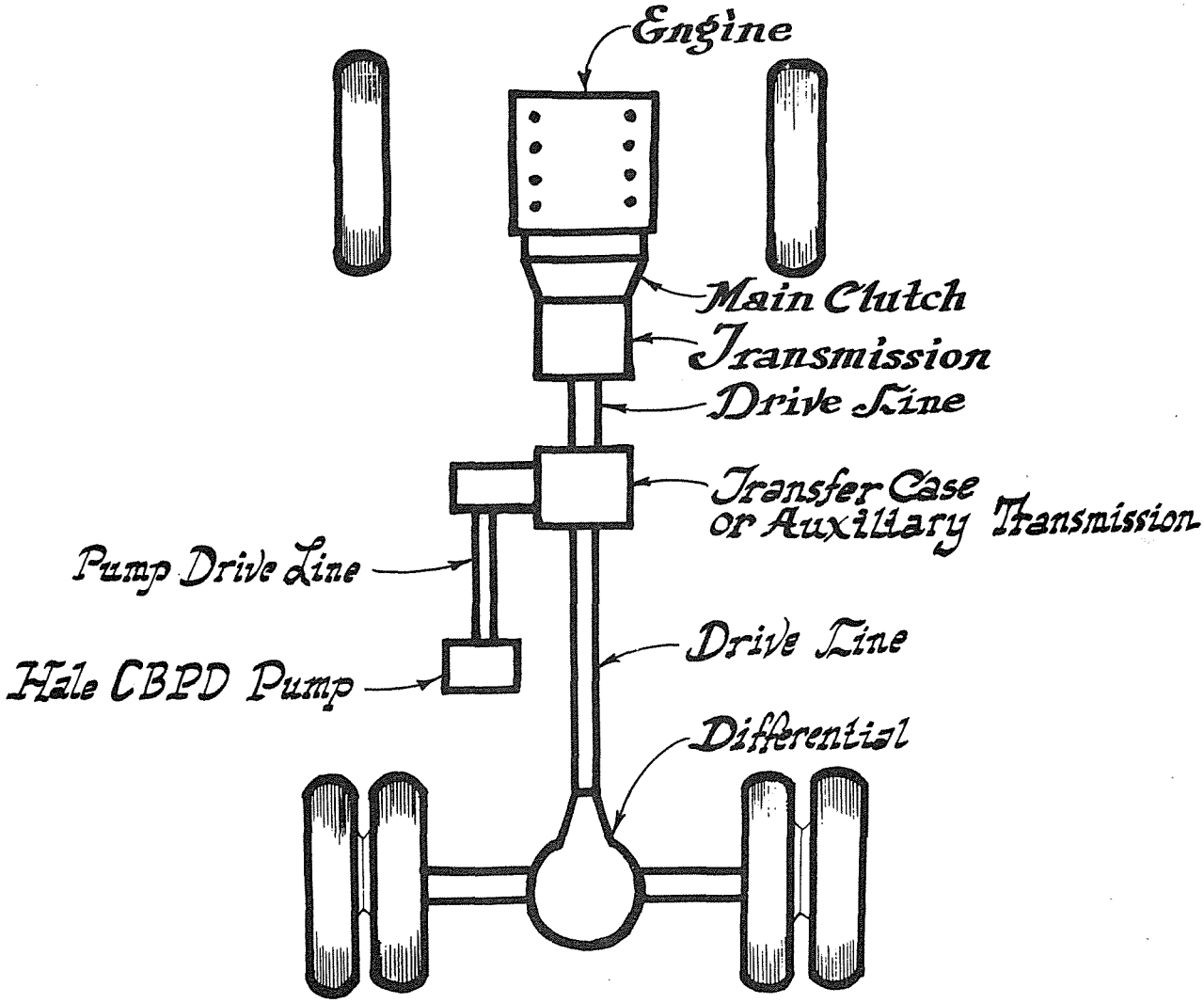
THIS TYPE OF HOOK-UP SHOULD BE EMPLOYED ONLY WHEN ABSOLUTELY NECESSARY, BECAUSE OF POSSIBLE FAILURES COMMON TO SUCTION OPERATION. ALSO, THE HEIGHT TO WHICH WATER CAN BE LIFTED IS CONSIDERABLY REDUCED BY EACH FOOT ADDED TO SUCTION LIFT

FIG. 17-D



EXHAUST PRIMER ARRESTER

FIG. 18



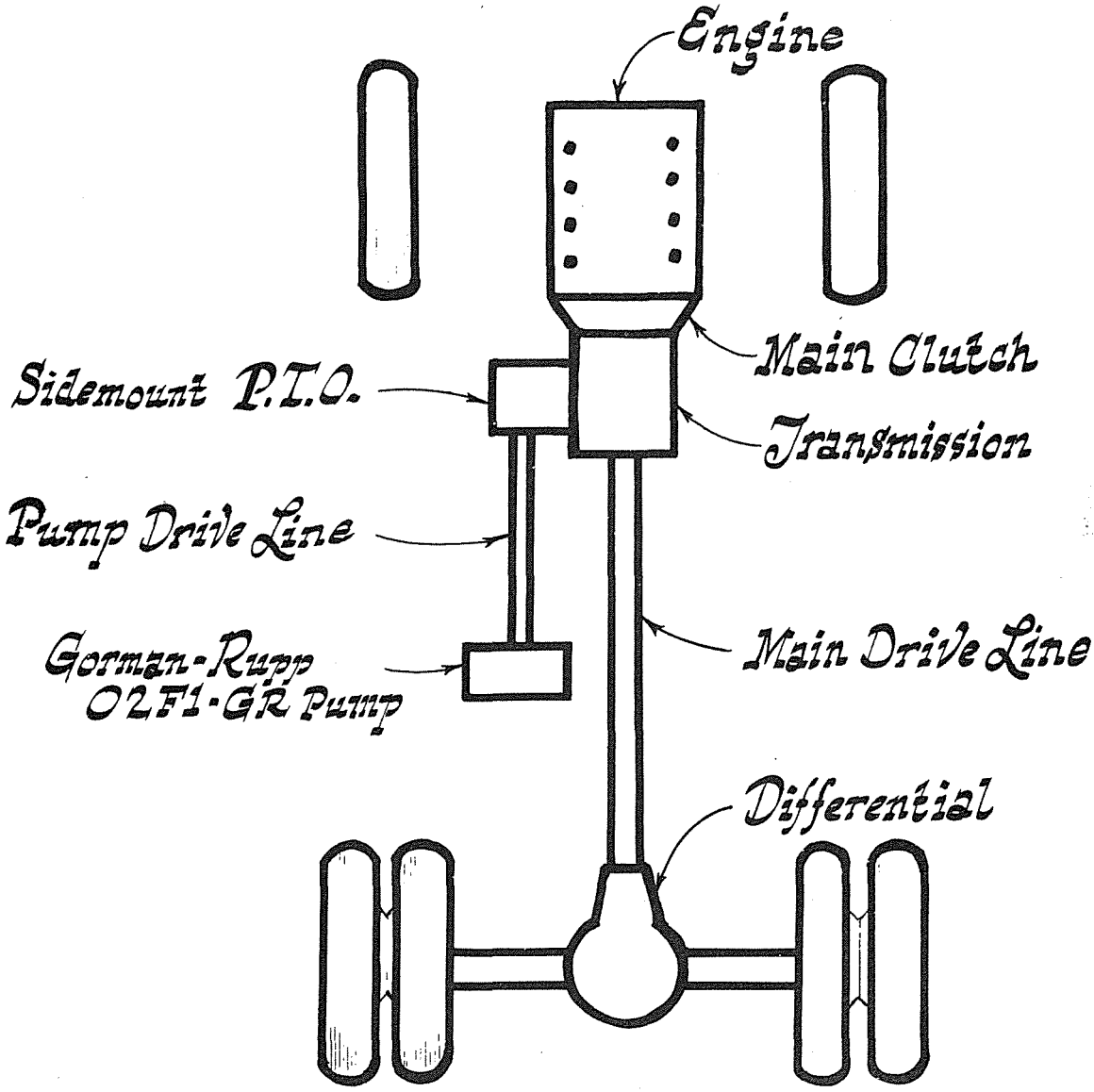
PRESENT CLASS 1 TANKER PUMP DRIVE CHARACTERISTICS

1. High Torque to Pump
2. Speed of Pump Dependent on Gear Transmission is in.
3. Main Truck Clutch Must Be Engaged to Transmit Power to Pump

RESULTS

1. High Volume and Pressure
2. Can "NOT" Make Running Attack

FIG. 19



PROTOTYPE CLASS III P.T.O. PUMP DRIVE

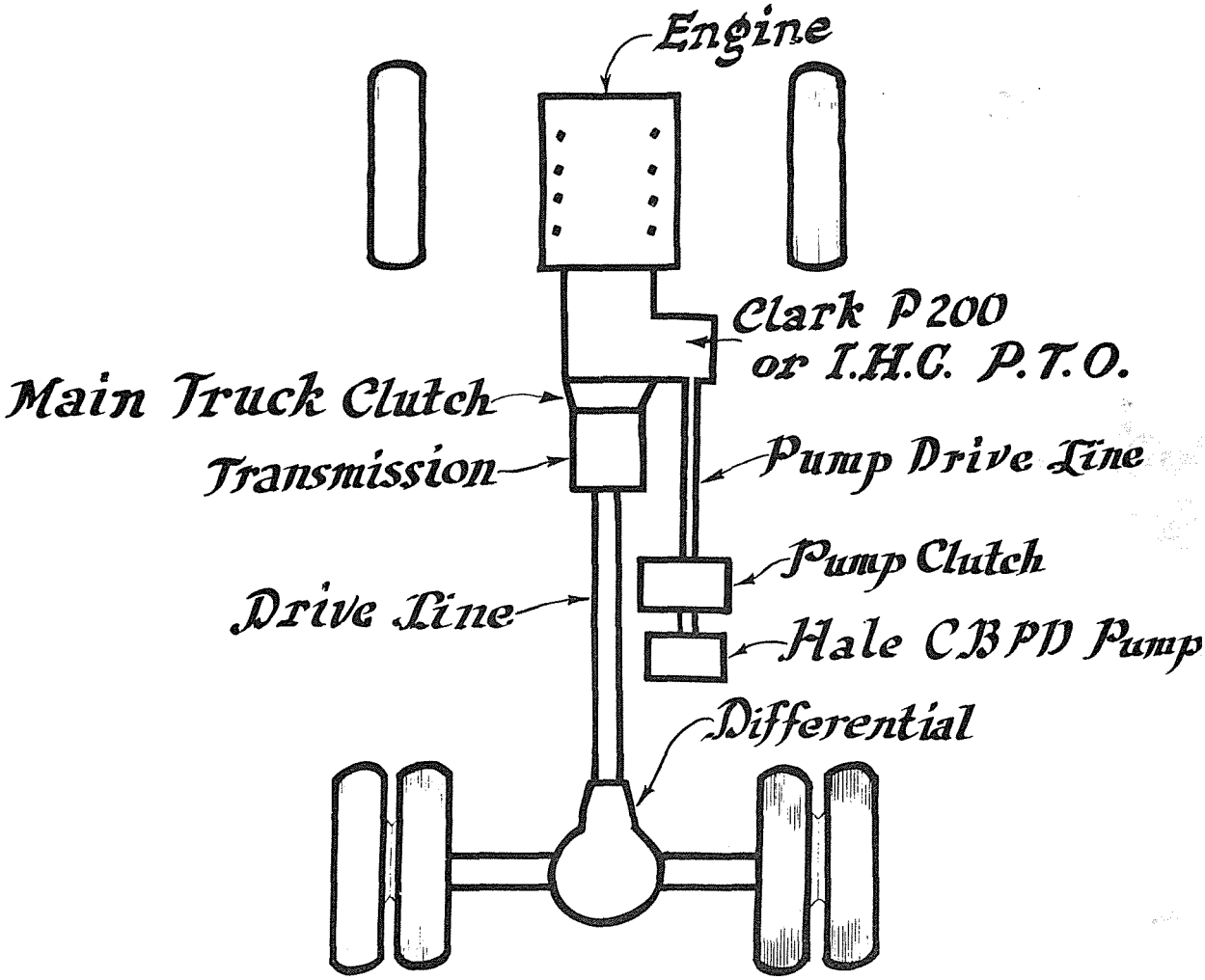
CHARACTERISTICS

1. Limited Torque to Pump
2. Speed of Pump Independent of Gear Transmission is in
3. Main Truck Clutch must be Engaged to Transmit Power

RESULTS

1. High Volume and Pressure Limited
2. Can Make Limited Running Attack

FIG. 20



PROTOTYPE CLASS I TANKER PUMP DRIVE CHARACTERISTICS

1. High Torque To Pump
2. Speed of Pump Independent of Gear Transmission is in
3. Power to Pump Independent of Main Truck Clutch Engagement

RESULTS

1. High Volume and Pressure
2. Can Make Running Attack

FIG. 21